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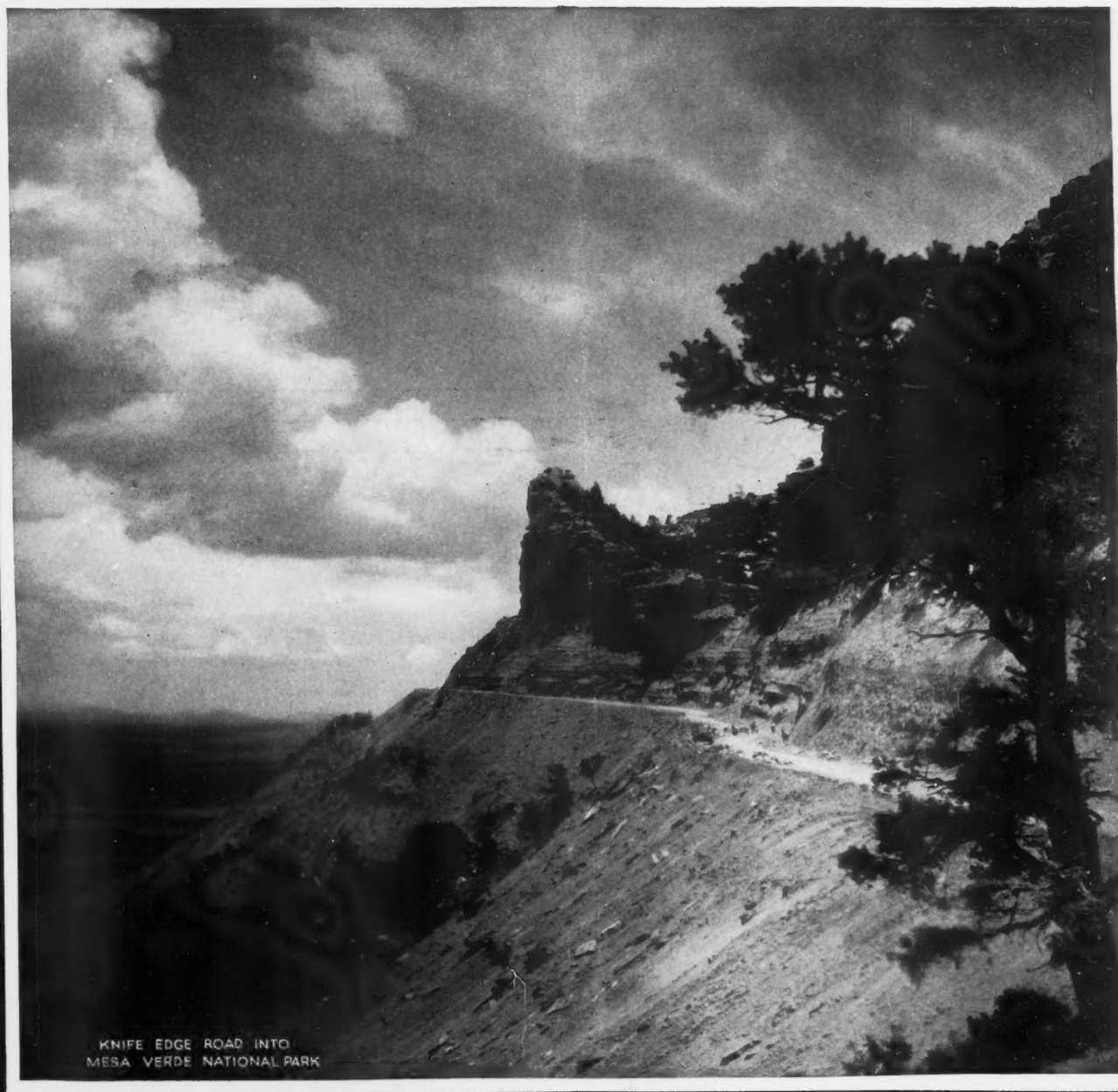
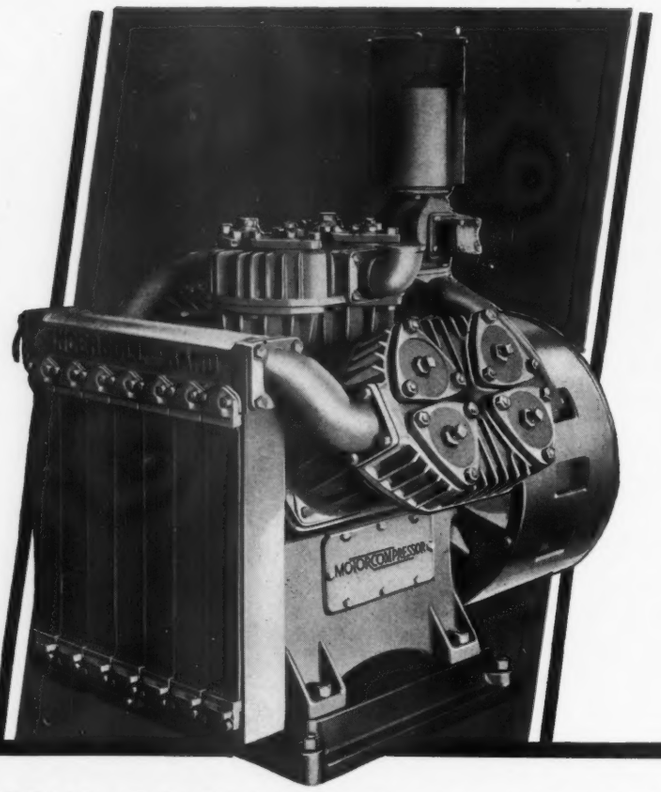


KNIFE EDGE ROAD INTO
MESA VERDE NATIONAL PARK

TWO NEW Compressors



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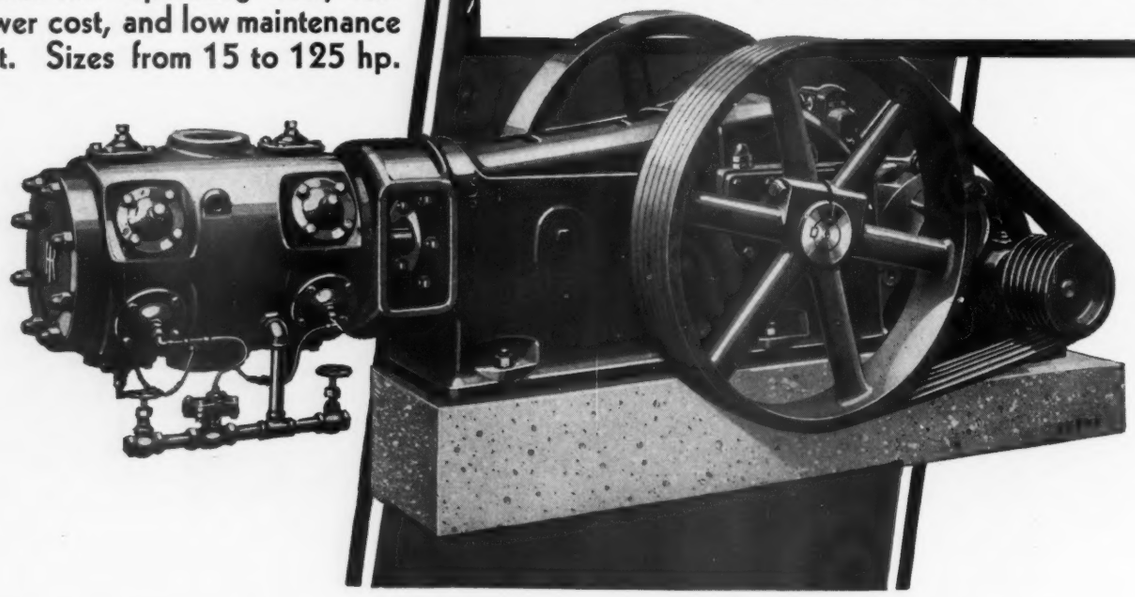


As It Seems To Us

COOLING HOOVER DAM

THIS issue contains an article describing one of the most interesting phases of the work at Hoover Dam: the method and the equipment for removing from the great concrete barrier the heat which will be generated by the setting of the cement. Such a procedure is unprecedented, but in no way experimental. It is possible to determine beforehand just what the cooling will accomplish. Nevertheless, because it is unique, this operation will engage the attention of construction men the world over.

As our article explains, the 40° temperature rise resulting from the chemical reaction of the cement will necessitate the removal of 128,345,000,000 Btu's from the 3,325,000 cubic yards of concrete to be poured. Some idea of the magnitude of the task this imposes may be gained if it is stated that this amount of heat is sufficient to melt a block of ice weighing 445,642 tons!

Climatic conditions had to be taken into account by the engineers when they computed the amount of cooling effect that would be needed. In January, when the mean temperature in Black Canyon is 52°F., the maximum temperature of the concrete will be 92°; but in July, when the monthly mean temperature is 93.8°, the concrete will have an extreme temperature of 133.8°. Accordingly, it will require more than twice as long in July as in January to cool the mass to the specified point. It is expected that it will take more than 70 days to extract the surplus heat during the peak of hot weather.

The installation and operation of the cooling plant which the contractors have set up to perform this important function was listed in the unit cost figures of the bid at $360,000. Assuming this estimate closely to approximate the actual cost, about eleven cents per cubic yard will be spent in extracting the heat from the concrete. This will make possible some minor monetary savings on grouting; but, of more importance, it will insure the great structure against any inherent weakness. If the innovation proves successful, and there is no doubt that it will, probably every large concrete dam built henceforth will be similarly cooled.

It is said to be the dream of every architect to put up a building that will stand until decay sets in without developing a crack. Because of conditions beyond their control, few ever achieve this ambition. If designing engineers harbor similar longings concerning dams, it seems probable that Hoover Dam will fulfill their desires. Excluding earthquakes, it is hard to conceive of any force that will disrupt the unity of the huge stopper that is being placed in Black Canyon with all the thorough preparation and care of execution that a renowned surgeon might expend upon a major operation.

HEADLIGHTS AND SAFETY

AN automobile without headlights would manifestly endanger the lives of all persons on the road where it was being driven. However, the mere provision of shafts of light in front of a car does not remove the hazard. Unless the beams are properly directed, they may be a distinct menace to safety and defeat the very purpose which they are supposed to serve. The glare from cars traveling in the opposite direction is the bugbear of the night driver, and causes even careful motorists to become involved in accidents for which they cannot fairly be held accountable.

The public-safety department of the Automobile Club of Southern California points out the changes in the mechanics of the human eye that are caused by glare. When exposed to strong light, the pupil of the eye rapidly contracts to its minimum size, and through this small opening it is impossible for an adequate image of the field of vision to be recorded upon the retina. If the pupil could then open as fast as it had contracted, the danger would be minimized, but it cannot do this. It takes approximately 60 times as long for it to regain its normal dimensions as it did for it to grow small. Thus, if a driver is subjected to a strong glare, it may require only a twentieth of a second for the pupil to contract, but it will take three seconds for it to reopen completely. During the interval, he is blinded. If he is traveling at 40 miles an hour, he will traverse 176 feet of roadway before he again has normal vision. This, of course, is sufficient to side swipe a car, strike someone walking beside the highway, leave the road and plunge into a ditch, or collide with some object.

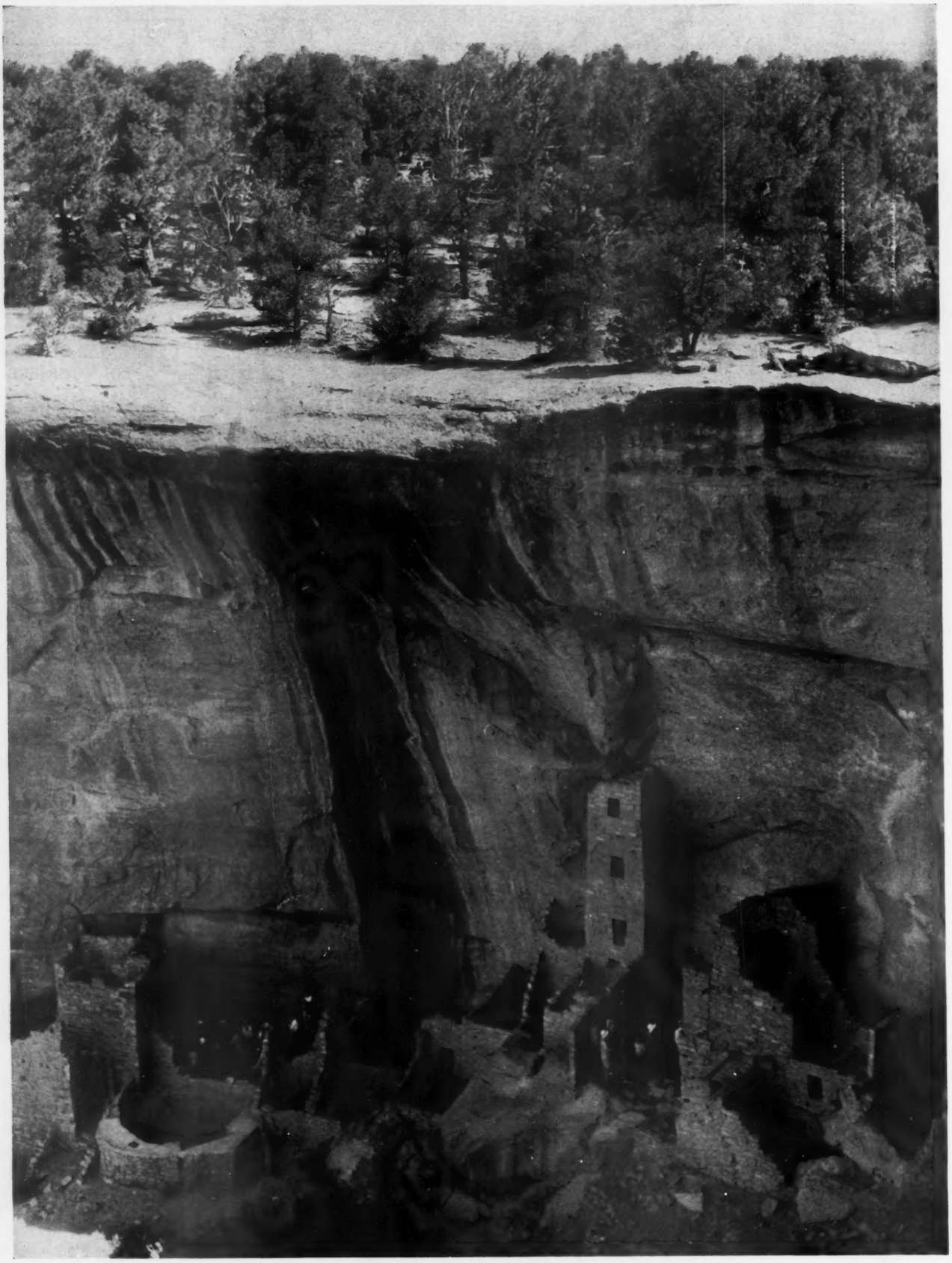
These figures bring home the urgency of keeping headlights in perfect and legal adjustment to guard against causing the other fellow a mishap. Even when lights are correctly cared for they may cast a blinding glare when the car is topping a rise in the roadway. Illumination engineers have contended for a long time that the highways, themselves, should be lighted, much as our principal city streets are at present. Several model stretches of roadway have been equipped with overhead lighting and are undergoing study to find out if they lessen accidents. Such lighting systems would, of course, increase the burden on the taxpayers unless some means could be found to assess their cost to motorists only.

NICKEL'S GOLDEN JUBILEE

ONE does not have to be a graybeard to remember when the metal "nickel" was comparatively little used other than for coinage and for such ornamental purposes as plating on the decorative portions of the coal range, to which mother pridefully and industriously imparted a mirrory luster once a week. Indeed, nickel was a rare metal just a few generations back; but 50 years ago the great nickel-copper deposits near Sudbury, Ontario, were uncovered. Canadians recently observed the golden jubilee of this fortuitous find which gave rise to the world-known International Nickel Company and contributed notably to the development of northern Ontario.

Nickel, today, has multifold uses, most of them attributable to the unremitting research of its exploiters. Despite the lagging pace of world industry, its annual consumption is now 20,000 tons greater than during the height of wartime activity. Ninety per cent of this material comes from the Sudbury district. Thus far, the mines there have produced nickel and copper valued at $500,000,000, and have paid $145,000,000 to stockholders in dividends. More than 30,000,000 tons of ore have been dug and smelted. Only about 6 per cent of the known deposits have been recovered, and there remain in the ground reserves sufficient to supply all the world's nickel requirements and 5 per cent of its copper needs for the next century.

Next year Toronto, another illustrious Ontario community, will celebrate the centenary of its existence under its present name. Toronto of today is the outgrowth of the third settlement on that site. In 1750 the French built Fort Rouille there, only to burn it nine years later to keep the British from capturing it. New buildings rose, however, and in 1793 Governor Simcoe made it the capital of Upper Canada and named it York, in honor of the Duke of York. In 1812, United States troops seized and burned it, but again it grew up, Phoenixlike, from its ashes. By 1834 it was a thriving town of 9,000 souls, and it was then that its name was changed to Toronto, Indian for "a place of meeting". The city plans to observe its birthday with elaborate ceremonies to be distributed over the period from March to August.

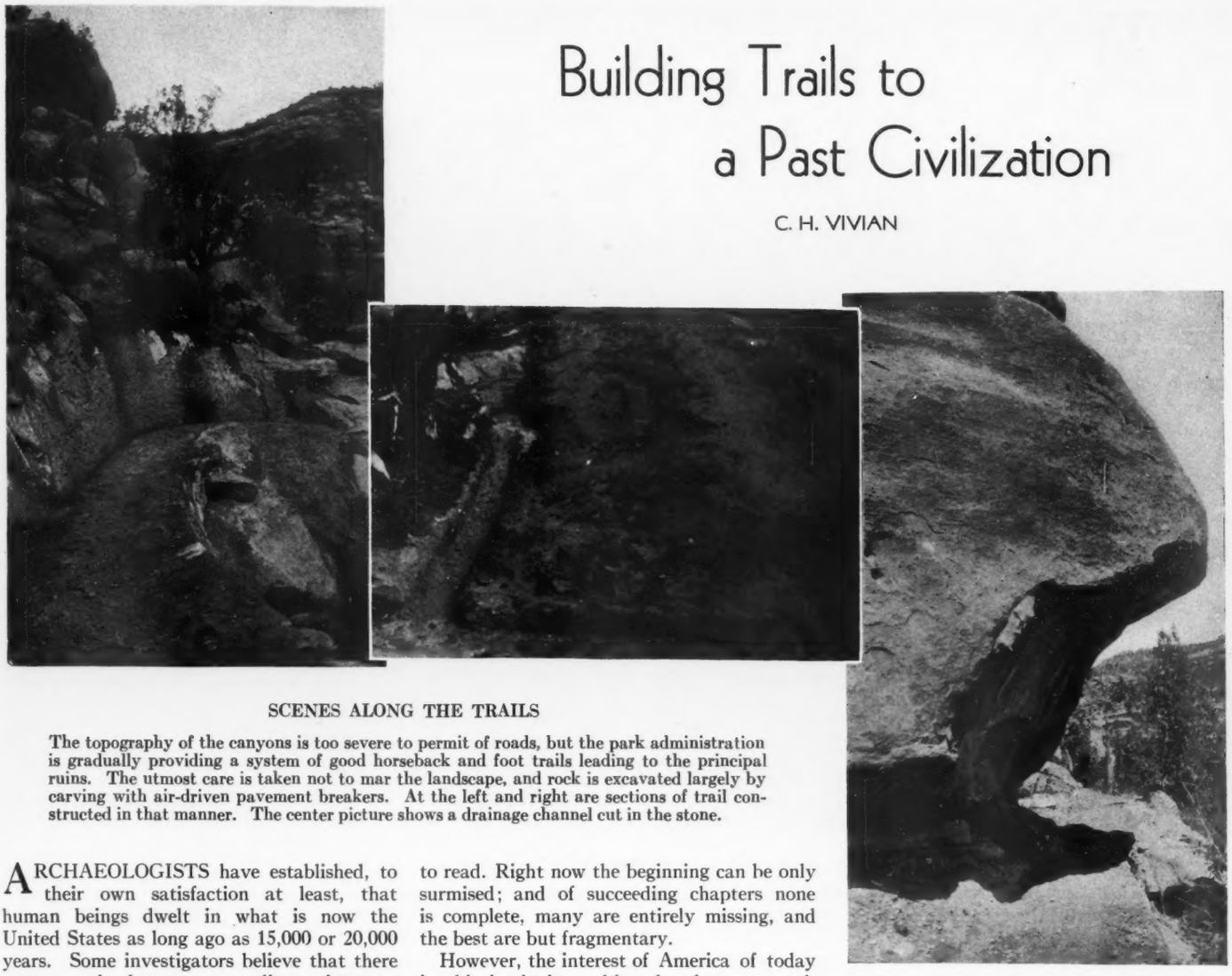


SQUARE TOWER HOUSE, EXCAVATED AND REPAIRED

This cliff dwelling dates from about the year 1204. It occupies a shallow cave which is approximately 138 feet long. The most conspicuous feature of this ruin is the tower in the center. It rises 35 feet above the large rock which serves as its foundation. The back of the cave forms the rear wall of the tower.

Building Trails to a Past Civilization

C. H. VIVIAN



SCENES ALONG THE TRAILS

The topography of the canyons is too severe to permit of roads, but the park administration is gradually providing a system of good horseback and foot trails leading to the principal ruins. The utmost care is taken not to mar the landscape, and rock is excavated largely by carving with air-driven pavement breakers. At the left and right are sections of trail constructed in that manner. The center picture shows a drainage channel cut in the stone.

ARCHAEOLOGISTS have established, to their own satisfaction at least, that human beings dwelt in what is now the United States as long ago as 15,000 or 20,000 years. Some investigators believe that there were people here even earlier. Anyway, there is ample evidence that, if the complete history of the region we occupy were assembled, the portion dealing with the period since Columbus would make up only a small fraction of the volume. The first part of the book is almost entirely missing, of course, but scientists each year piece together a little more of the chronicle. The early Americans, they contend, were not of a race now vanished, but were, in reality, the direct forebears of the American Indian. It is their belief that the original emigrants to these shores were Mongols that came by way of the Bering Straits. If we accept this theory, all Indians, whether Peruvian or Ute, sprang from a common ancestor and are of the Mongoloid race.

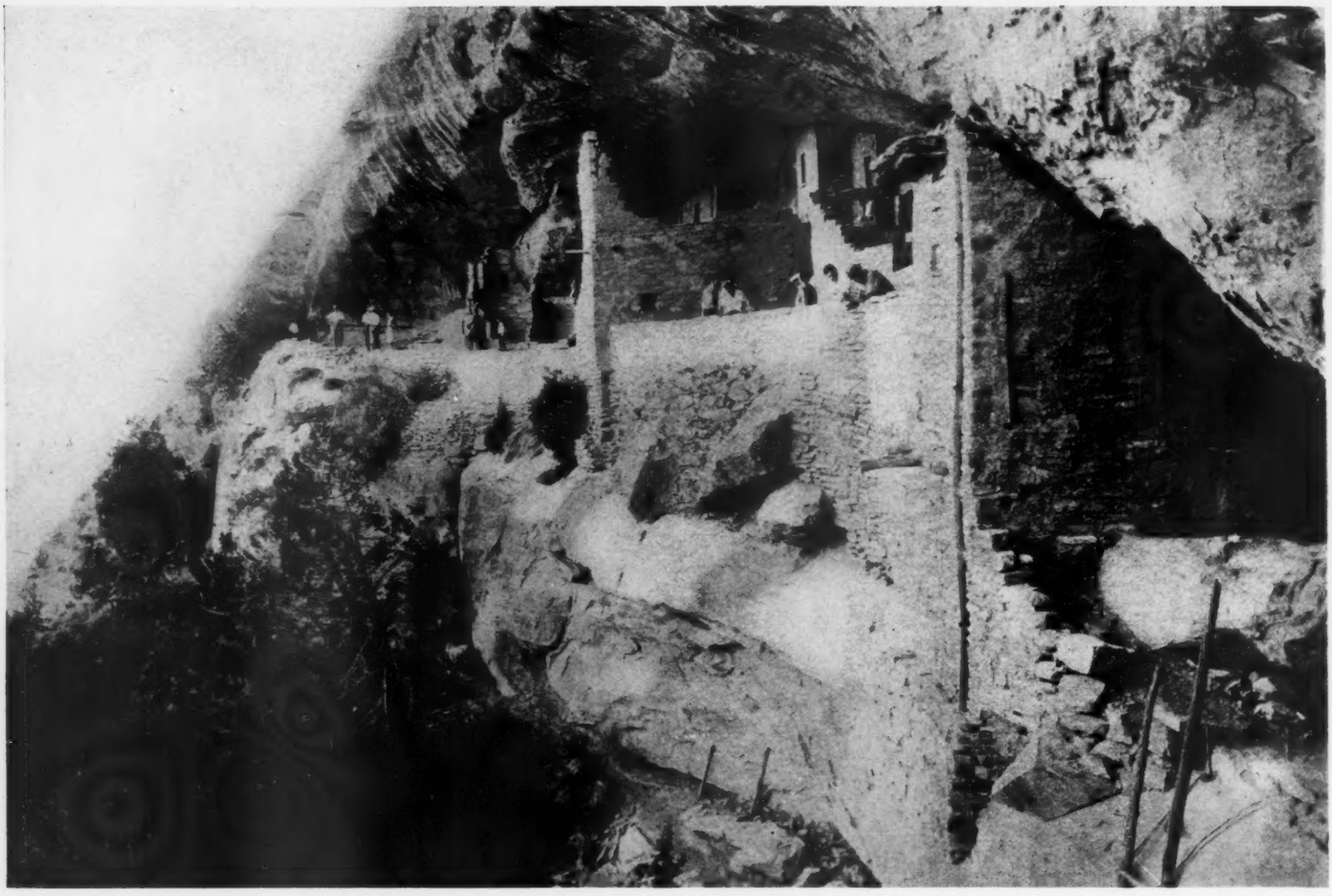
It is well known that scientists have barely begun to unearth America's past. The excavations that have thus far been made are but scratches compared with the work that is to be done. Approximately 100 scientifically trained searchers are diligently engaged in the hunt now, but the work is so tedious and the interpretation of discoveries is such a slow and involved process that the complete unraveling of our antiquity must necessarily be left to future generations, for the farther back the story is traced the harder it becomes to read. Right now the beginning can be only surmised; and of succeeding chapters none is complete, many are entirely missing, and the best are but fragmentary.

However, the interest of America of today in this intriguing subject has been aroused. Digging in mounds and sifting tons of dirt to glean a few possessions of people long since dead are no longer regarded as signs of personal idiosyncrasy. Persons of means have come to realize that the archaeologist is hunting the pieces of an absorbing jigsaw puzzle whose patching together will reveal much that is worth knowing. Gifts and endowments to enable these scientists to broaden their activities have, accordingly, become more frequent and more generous.

Thomas Jefferson is credited with having been the first American to inquire in a practical way into the lives and habits of our early inhabitants. A mound of earth near his home in Virginia captured his attention, and in 1781 he began to dig in it. Encouraged by the discovery of a few arrowheads, he excavated the entire site. His efforts divulged rude tools of stone, some earthenware pots, and a considerable collection of human bones. Twenty years afterward he described the operations in a monograph, *Notes on a Barrow in Virginia*. This was our country's first archaeological report.

Thereafter interest in mounds increased; but the major archaeological endeavor has been expended in Mexico and Central America where the ruins are larger and more spectacular than those closer home. Such finds as have been made in the United States have come about largely by accident rather than by design. Some ditch diggers in Minnesota unwittingly made one of the most important contributions to our store of knowledge when they uncovered a human skeleton. Fortunately, they had the presence of mind to report the find, and Prof. Albert E. Jenks, of the University of Minnesota, determined the bones to be those of a young girl of Mongoloid type. He expressed the belief that she lived 20,000 years ago.

From our present limited store of relics of those remote periods we can do little more than speculate upon what sort of people lived here ten or twenty centuries ago and upon how far they had carried their civilization. As we come nearer our own time, however, our knowledge grows more definite; and in several parts of the country the opening and the restoration of ruins are gradually enabling trained scientists to read the story that is there. One such area which has already yielded much information and which promises to continue as a prolific field of knowledge is Mesa Verde National Park in Colorado.



WHERE A FEW COULD REPEL A HORDE

This is Balcony House, one of the more recently built cliff structures and one whose location indicates that it probably was a fort. Not only was its site extremely difficult of access but special works were constructed to give the position added strength against an enemy. The ruin derives its name from a balcony which served as a terrace and provided a means of communication between the upper rooms.

This upland section is distinctive because of its cliff dwellings, but has also produced important ruins of other forms. It is the largest piece of ground in the nation that has been made a preserve because of the antiquities it contains. It has been a national park for more than 25 years, but because it is off the beaten path it has had few visitors.

The park's name means "green table," and while the green is not always a predominating characteristic because of the aridity of the region, there is never any doubt about the general appropriateness of the title. In some past geological era there occurred a major displacement along a fault plane which marks the northern boundary of the park. As a result, an almost perpendicular cliff, 2,000 feet high, was formed. Despite the accumulation of talus in the intervening years, the slope is still a sharp one. This north rim or edge is projected far above the Montezuma Valley; and from the approach road to the park one may look down, as though from an airplane, upon a vast expanse of territory. At some points it is possible to see into any one of the four states of Colorado, Utah, Arizona, and New Mexico. Mountains as far away as 115 miles are easily visible on a clear day, and 45 miles to the south, in the midst of a sandy, mountain-rimmed plain, rises a great mass of igneous rock. It bears such close resemblance to a sailing vessel that one almost knows without being told that its name is Ship Rock. This unusual natural creation is 1,860 feet high.

Mesa Verde slopes from north to south, terminating at a cliff above the Mancos River, which cuts across it. Although rains are infrequent, they are often heavy, and through countless generations the run-offs from these downpours have carved deep canyons which extend back from the Mancos at various points and which grow gradually narrower and shallower as they project into the tableland. The combination of this erosion and of the character of the geological formation in which it has taken effect served to set up the peculiar conditions which gave the cliff dwellers the sites which they converted into their homes. Immediately beneath the surface of the mesa are sedimentary strata, consisting of alternate layers of sandstone, clay, and gradations between the two. These lie in virtually horizontal position. The upper member of the series is a band of sandstone which, although relatively soft as sandstones go, is much more resistant to weathering agencies than the material next underlying it. This sandstone forms the top of the table and is responsible for the uniform surface that exists there save where the canyons have eaten their way into and through it.

After the water and other erosional forces had cut through this protective mantle they encountered the softer materials, and it was but natural that, here and there, they should extend back under the sandstone cap a few feet and hollow out openings. The removal of the support for the sandstone in these places caused it to spall off at the bottom; and, as this continued through the ages, round-roofed caverns of various heights, depths, and lengths were formed. In these shelters the Indians took refuge from the elements and from their enemies, constructing communal dwelling places. They were inaccessible from above, and their approaches, by way of the steep talus slopes in front of them, were easy to command. After their abandonment, further crumbling of the sandstone roofs, together with wind-blown dust, covered them partially or entirely and preserved them much as they were when they were occupied. Thus far approximately 800 of these ruins have been located, but only a few of them have been excavated and restored.

Evidence unearthed from these cavernous sites shows that the cliff dwellers were primarily an agricultural people. They emerged from their aeries underneath the rock to cultivate patches of poorly productive land atop the

AN APARTMENT HOUSE 860 YEARS OLD

This is the largest ruin thus far unearthed in the park. It was discovered in 1888 by two ranchers searching for lost cattle. They named it Cliff Palace, an unfortunate designation, as it was in no sense a palace. It contained more than 200 dwelling rooms and 23 sacred rooms or kivas. Some of the structures were four stories high. The cave is more than 300 feet long and high up on a canyon wall.

arid mesas that ran tonguelike among the deep arroyos. Corn was the principal crop and the chief source of subsistence. Game was scarce and hard to stalk. A few berries and nuts were procurable, and the Mancos yielded some trout. The corn was ground on flat stones called metates, and from the resultant meal was made bread which was baked on stone griddles. Such meat as they had was boiled in earthenware vessels. Since corn was the essence of life to them, it is small wonder that, in their dependence upon rain and sunshine, these people worshipped the sun as the father of all things and the earth as the mother.

The cliff dwellers had no written language, but used a few symbols to record their thoughts. These they painted on earthenware jars or scratched upon the cliffs. They made cotton cloth and knew how to decorate it. They were skillful enough in ceramic work to produce all the utensils they required, and these, too, were embellished with figures. They wove attractive baskets from vegetable fibers. From stone they fashioned axes, spearpoints, and rude tools. They knew how to make sandals of leather.

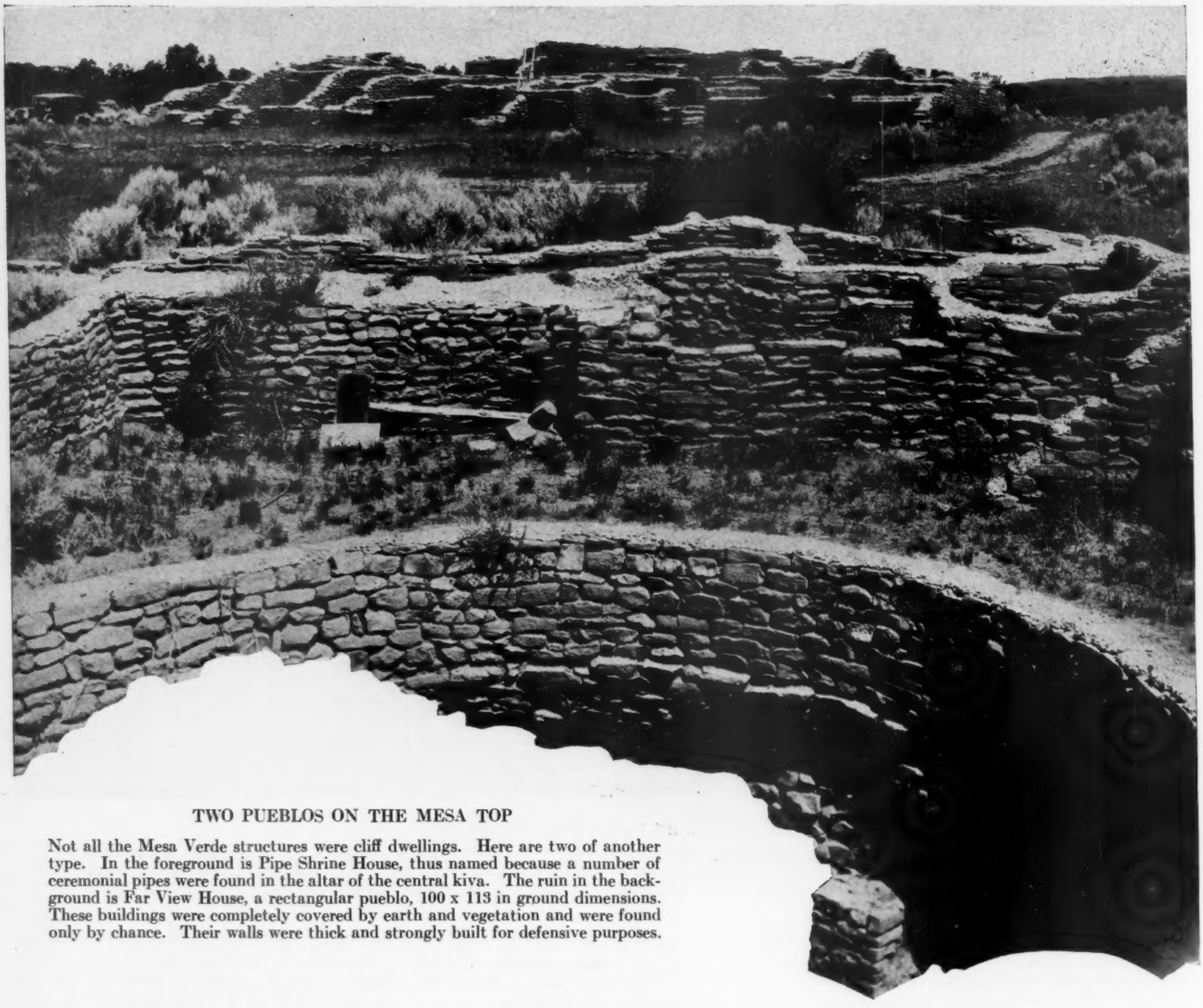
The cliff dwellers, then, were an industrious race, with fixed abodes. They were resourceful and had a certain culture and a sense of beauty that stamp them as well along the road to civilization. Their ancestors doubtless lived in the bare caves beneath the overhanging sandstone ledges, but this primitive method of housing did not satisfy them. Instead, they built well-constructed houses of stone, shaping the individual pieces and laying them one on top of another with such care that the structures have withstood the elements for centuries. Fortunately, the ruins reveal examples of the habitations of a number of generations of these people. We cannot go into a detailed description of them here: the reader that is sufficiently interested is referred to Government publications or to the writings of the archaeologists that have studied the Mesa Verde area. A general knowledge of the cliff dwellings can be gained from some of our illustrations and also from the following discussion which is extracted from the circular of general information regarding Mesa Verde National Park which is published by the Department of the Interior:

"The earliest culture so far identified on the Mesa Verde is the so-called 'Late Basket-Maker Culture', first found in Step House Cave on the west side of the park. These early inhabitants constructed roughly circular, semisubterranean cysts or rooms in the sandy floors of caves and in the shallow red soil along the watershed divide of the flat mesa lands between the various canyons. The floors were sunken slightly below the surface, and the low walls plastered with clay or reinforced with thin slabs of stone set on end or balls of mud and clay laid up as masonry.

"A vaulted roof of logs, further supported by upright posts set in the floor, carried the thatching and heavy covering of clay and earth that insulated the structure from the elements. A small vent in this roof cared for the egress of smoke from the fire pit within. Entrance was normally by a small doorway in one side. There are hundreds of such sites. Up to this time excavations have failed to uncover a single house structure of this type not destroyed by fire.

"These early inhabitants made basketry, excelled in the art of weaving, and were the first to invent fired pottery. The course of this invention can be traced from the crude sun-dried vessels tempered with shredded cedar bark to the properly tempered and durable fired vessel.

"Then followed a long development in house structure, differing materially from this earlier type. Horizontal masonry replaced the cruder attempts at house-wall construction; rectangular or squarish forms replaced the somewhat circular and earlier type; and



TWO PUEBLOS ON THE MESA TOP

Not all the Mesa Verde structures were cliff dwellings. Here are two of another type. In the foreground is Pipe Shrine House, thus named because a number of ceremonial pipes were found in the altar of the central kiva. The ruin in the background is Far View House, a rectangular pueblo, 100 x 113 in ground dimensions. These buildings were completely covered by earth and vegetation and were found only by chance. Their walls were thick and strongly built for defensive purposes.

gradually the single-room structure was grouped in ever-enlarging units which assumed varying forms of arrangement as the development progressed. The art of pottery making improved concurrently with the more complex house structure.

"The arrangement of houses in a cliff dwelling of the size of Cliff Palace is characteristic, and is intimately associated with the distribution of the social divisions of its former inhabitants.

"The population was composed of a number of units, possibly clans, each of which had its more or less distinct social organization, as indicated in the arrangement of the rooms. The rooms occupied by a clan were not necessarily connected, although generally neighboring rooms were distinguished from one another by their uses. Thus, each clan had its men's room, which is ceremonially called the kiva. Here the men practically lived, engaged in their occupations. Each clan had also one or more rooms which may be styled the living rooms, and other inclosures for granaries. The corn was ground in another room containing the metate set in a stone bin or trough. Sometimes the rooms had fireplaces, although these were generally in the plazas or on the housetops. All these different rooms, taken together, consituted the houses that belonged to one clan.

"The conviction that each kiva denotes a distinct social unit, as a clan or family, is supported by the general similarity in the masonry of the kiva walls and that of adjacent houses ascribed to the same clan. From the number of these rooms it would appear that there were at least 23 social units or clans in Cliff Palace. The kivas were the rooms where the men spent most of the time devoted to ceremonies, councils, and other gatherings. In the social conditions prevalent at Cliff Palace, the religious fraternity was limited to the men of the clan.

"Apparently there is no uniformity in the distribution of the kivas. As it was prescribed that these rooms should be subterranean, the greatest number were placed in front of the rectangular buildings, where it was easiest to construct them. But when necessary these structures were built far back in the cave and inclosed by a double wall, the intervals between whose sections were filled with earth or rubble to raise it to the level of the kiva roof. In that way they were artificially made subterranean, as their beliefs required."

In addition to residential buildings, Mesa Verde contains numerous ruins of cliff structures that did not serve as habitations. Some of these are coeval with the cliff dwellings. Two of them, Sun Temple and Fire Temple, were religious edifices. Sun Temple, situated on top of a high cliff and shaped in the form of the letter D, has extreme dimensions of 131.7x64 feet. It contains 1,000 feet of walls which average 4 feet in thickness and were constructed double, with cores of rubble and adobe. The excellence of this masonry and the presence in the building of decorated stones distinguish Sun Temple as the finest architectural work so far unearthed in the park. It is believed to have been built through the joint efforts of workmen from the neighboring cliff dwellings who daily made the trip from and to their homes over still discernible trails down the sides of the

cliffs. Fire Temple occupies a shallow cave and appears to have been the worship house of the fire cult. It is rectangular, with massive-walled, 2-story buildings flanking a central court containing a fire pit. There is some evidence that a fire burned there at all times, at least one was kindled there during the native fire dances.

Supplementing the buildings associated with the cliffs are other structures occupying sites on the mesas which separate the canyons. These have been classified as belonging to the later cultures of Mesa Verde. They resemble the Indian pueblos which are found in other parts of the West. They are rectangular, with the kivas protected by adjacent and outer living and storage rooms. They are well-built, compact structures which afforded excellent protection from attacks. These pueblos, each occupied by a clan, were grouped into cities of great defensive strength. From them, the farmers went forth to the nearby fields.

By means of the remarkable system of tree-ring chronology, developed by Dr. A. E. Douglass of the University of Arizona, it has been possible to determine with accuracy the dates of construction of the principal ruins in Mesa Verde Park. This ingenious scheme was worked out by Doctor Douglass in connection with his astronomical studies. Knowing that the recurrence of sun spots every eleven years affects weather conditions, and that these, in turn, influence the rate of growth of trees, he began the examination of the annular growth rings of trees as revealed in sawed sections. Using growing Arizona pines, he traced the record back as far as possible. Next he collected beams from Hopi pueblo ruins in Arizona. Gradually, by securing specimens whose outer rings dovetailed with the inner or core rings of younger trees, he was able to trace the succession back for 500 years, save for the interval from 1650 to 1725, for which span the trees failed to disclose the expected 11-year cycle. Old astronomical records reveal that no sun spots were evident during those years, and thus was verified the relationship between solar changes and tree growth.

Upon continuing his investigations with beams from various ruins, Doctor Douglass was able to establish a complete tree-ring chronology extending back to the year 700 A.D. By comparing sections from the beams in the Mesa Verde ruins with this master series it was possible to fix definitely the year in which each of the respective beams was cut; and, on the assumption that they were used in those same years, the dates of construction of the major ruins were established. Thus Cliff Palace was determined to have been built in 1073. Spruce Tree House, which archaeologists had correctly classified as one of the most recent structures, was found to contain beams dating from 1216 to 1262.

Tree-ring chronology reveals that a 23-year drought was experienced from 1276 to 1299. As no Mesa Verde structures built later than 1262 have been unearthed, the plausible explanation is that the Indians were forced to abandon the region during this period and to seek another one of more plentiful water supply. The remains of an extensive series of ancient masonry dams in the canyons indicate that they strove desperately but ineffectively to collect sufficient water to meet their needs. If, as is probably true, Cliff Palace was occupied from the time of its construction until the exodus of the cliff dwellers, it was tenanted for more than 200 years.

The only way to see Mesa Verde with any degree of thoroughness is by horseback or on foot. Roads permit access to a few ruins, but to reach the others one must take to the trails. The building of additional highways and trails that will enable visitors to extend the range of their trips comprises one of the chief activities of the park administration; but the country to be covered is so expansive that comparatively little progress towards the ultimate goal can be made in any one year with the limited appropriations available.

MODERN DIGGING METHODS

In what was probably the domain of their own forebears, Indians from the Ute and Navajo reservations near the park now do much of the construction work there. Modern methods and machinery make their tasks easier. The workmen here shown are excavating with the aid of a "Jackhamer." Two Indian boys are shown at the top.

With what seems peculiar appropriateness, fate has decreed that in this domain, which is devoted to the study of the early American Indian, much of the development work should be done by members of the living Red race. Most of the labor force, which ranges up to 80 men during the park season of June 1 to October 1, is drawn from the nearby Navajo and Ute Indian reservations. As these people rely chiefly for their existence upon uncertain crops and the sale of rugs and other products of their handicraft, the employment that comes to a few of their number through the Government is very welcome. As workmen, these Indians are strong and willing and are fully as satisfactory as white men. Up to 1933, a total of 57 miles of trail had been built, much of it by Indian labor.

The construction of roads and trails within the park presents some distinctive and interesting features. Because of the desire to retain, as far as possible, the appearance of the region as it was when the cliff dwellers lived there, every effort is expended to avoid undue scarring of the landscape. Owing to the sparseness of the vegetation and the aridity of the section, especial care must be taken to carry out this policy. Accordingly, unusual methods are followed. When new roads are built, they generally deviate from former travel lines. Instead of leaving the old roadways to the ravages of the elements, efforts are made to give the areas traversed their original aspect. To accomplish this, the disused rights of way are planted with native grass, shrubbery, and trees.

On new construction, blasting is resorted to infrequently because it is desired to displace as little ground as possible. Where conditions require the use of explosives, woven wire mats, similar to those employed in city excavations, serve to prevent rocks from flying. The dual purpose of this procedure is to eliminate injuries to trees and other growing things and to check the promiscuous scattering about of dirt and rocks. The displaced material is carefully arranged in fills. Slopes on the outer edges of elevated sections and those which flank cuts are finished with exceeding care, and the rocks and earth are disposed so as to present surfaces that conform to the surrounding country. These slopes are then planted with grass, cacti, and cedars so as further to increase their similarity to the adjacent terrain.

Where drainage ditches must be dug at roadsides, blasting is seldom employed. Instead, CC-45 pavement breakers are called into play. Working in soft sandstone, these air-operated tools quickly carve shallow channels without tearing out superfluous rock and thereby causing objectionable scars. The Indian laborers quickly become skilled in the operation of the pavement breakers. Compressed air is supplied by an Ingersoll-Rand Type 20 portable air compressor. In the building of both roads and trails, excess dirt and rock that cannot be utilized in making required fills is loaded into wheelbarrows and disposed of at points hidden from view.

Trails are constructed almost solely without the use of drills and blasting powder. Here, again, pavement breakers are used to excavate rock with a minimum of disfigurement of the landscape. Where walls must be built to retain earth or to provide approaches to bridges, dry rubble masonry is employed—the aim being to depart as little as need be from natural materials. Bridges are built of small cedar logs with rustic guard rails which retain the tree bark. Concrete is employed sparingly, its chief purpose being to seal the zones around culvert openings.

Trails are built 4 feet wide, which is sufficient to accommodate horses or hikers. Their maximum grade is 15 per cent. A crew of seven Indians and one white foreman can build about four miles of trail in the 6-months' working period during which weather conditions are normally favorable to work.

The Light That Never Fails

M. A. RINER

THE crossing is almost over. Fogs, head winds, and rough seas have delayed the passage, but the captain has promised that the big ocean liner will be alongside her pier the following noon. The passengers are so accustomed to the trainlike regularity with which large steamers come and go that they immediately turn their attention to packing their belongings. A few wonder how, without a sight of the sun or stars for days, the captain has been able to thread his way across the trackless wastes of the Atlantic. Still fewer, who have the inclination to think beyond their own small problems, wonder how he points so accurately to their destination. No missing the harbor entrance by a few miles and having to turn north or south, as the case may be!

Wonderful, is it not? Twenty years ago—yes; but not today. With all the modern aids, navigation is about as difficult as and much less hair-raising than piloting a bus down Fifth Avenue, New York. The magnetic compass, affected not only by deviation and variation but by such things as a forgotten jackknife in the quartermaster's pocket, has been replaced by the gyro compass which points always true courses. No longer does the ship in the hands of a human steersman weave a drunken course and add many miles to the distance to be covered. The "Metal Mike", that supersensitive robot, never lets its charge wander more than a degree from the established route. The cumbersome "dipsey" sounding machine has given way to the efficient sonic depth recorder. These are only a few of the wonderful inventions which have taken the mystery and romance out of navigating a vessel and reduced it to a science.

As the ship approaches to within a few hundred miles of shore the captain takes advantage of the radio beacons to determine his exact position. By radio direction finder he takes bearings on two or more shore beacons. The intersection of these bearings plotted on his chart establishes his position as accurately as the street sign at the corner of Forty-Second Street and Fifth Avenue locates that famous intersection. A few hours later he picks up the flash of the lightship. Then in quick succession come whistling buoys, gas buoys, lighthouses, and finally the channel buoys that guide the way to a safe anchorage. So plainly marked is every reef, submerged wreck. and other obstruction that only a blind man could go astray.

The branch of the Government service that is responsible for these invaluable friends of the seaman is the Bureau of Lighthouses.

GIVING A LIGHTHOUSE NEW LUNGS

In equipping this lighthouse with new compressors it was essential that it continue to operate while the change was being made. This photograph shows how the problem was solved. The compressor at the left of the structure was set up on a slab of concrete, and a pipe connection made to the horns to keep them in service while the old compressors were being removed from the cramped quarters which housed them. When the space had been cleared, one of the new units was installed. The one which had been temporarily set up outside was then moved to its permanent location.

From the humblest lighthouse keeper, isolated from human companionship in some God-forsaken spot, to the superintendent who plans and directs the activities within his district, the motto of this group of men is, "The light shall not fail". Wherever you may go, whether it be on the coast line of our continental limits or among our insular possessions, you will find them safeguarding the shipping of our own and other countries.

The Third District of the Bureau of Lighthouses comprises all the area from Point Judith (Narragansett Bay) to Cape May, which is at the mouth of Delaware Bay, and from Sandy Hook to Albany. Included in it

is New York City, the foremost seaport of the world. Add to the stupendous tonnage of ships that comes and goes in overseas trade the coastwise shipping and the heavy maritime traffic through Long Island Sound and on the Hudson River, then you will have some idea of the tremendous responsibility under which this district labors.

As would be expected, the Superintendent of the Third District, J. T. Yates, is one of the ablest men in his profession. Always on the lookout for ways and means to increase efficiency, he has recently completed an interesting undertaking at New Haven, Conn. Formerly, two lighthouses guarded the entrance to this harbor. The plan was to rearrange them so that one lighthouse and one beacon would do the work of the two. The S. W. Ledge Lighthouse was selected to remain. New fog-warning equipment was required, as that installed had outlived its usefulness. First, two new 425-millimeter Typhon foghorns were purchased. These are equipped with automatic control providing for a 3-second blast every 20 seconds.

The problem of compressor replacement was a more serious and perplexing one. In the first place the compressor room was in the base of the lighthouse. The space was very cramped with the old compressors and was, furthermore, reached by a stairway of very limited dimensions. Secondly, the lighthouse could not be without air for its fog signals while the change was being made. Consequently, a temporary installation of one of the new units had to be made to serve while the old machines were being removed. The new equipment not only had to be compact and self-contained but had to permit of temporary installation with minimum expense and trouble. Neither could reliability be sacrificed in what was to become the permanent plant.

After careful investigation, Mr. Yates decided upon an Ingersoll-Rand oil-engine-driven air compressor as the one that would meet all his requirements. The particular size selected consists of a 5½x5, vertical, duplex Type 20 compressor direct connected to an I-R four-cylinder, 4-cycle oil engine, all mounted on a common sub-base of welded structural steel. The unit has a closed water-cooling system complete with radiator, pump, and fan. This feature, and the fact that the engine can be started by hand cranking, simplified the problem of temporary installation, as only two pipe connections had to be made—namely, fuel supply and compressed air to the foghorns. The over-all dimensions of the unit are: length, 6 feet; width, 2 feet, 4 inches; and height, 4 feet, 10 inches. The total weight is 2,100 pounds.

Before passing on to the installation, a few words describing the oil-engine air compressor, particularly as to how the short over-all dimensions and low weight are obtained without sacrificing reliability, would, it is believed, be interesting. Very little need be said about the compressor. It is of a size and type which Ingersoll-Rand Company has manufactured for a number of years and of which there are thousands in service. The engine, however, is a recent, and for that reason, interesting development. Every automobile owner knows that the high-compression gasoline engine has had difficulty in burning properly the standard grades of fuel on account of their unstable nature. To overcome this there have been put on the market so-called "anti-knock" gases.

The diesel engine, which is essentially a high-compression engine, has experienced the same trouble in handling the regular diesel fuel oils. Depending only on the heat of compression for ignition, it has been impossible to control the rate of combustion of the various components of the fuel. In the higher-speed engine the problem has been intensified, and maximum gas pressures of 750 pounds per square inch and higher are common practice. It is these maximum pressures which determine the size of the bearings, etc. The end has, therefore, defeated the means. The higher rotative speeds which were gone to in order to reduce weights have resulted in higher pressures which call for heavier parts. Either very little improvement in weight is obtainable by this means or the engine has a questionable margin of design safety. Special fuels, of course, cannot be considered. This would defeat the purpose of the diesel engine—namely, its capability to burn the ordinary run of inexpensive and readily obtainable fuels.

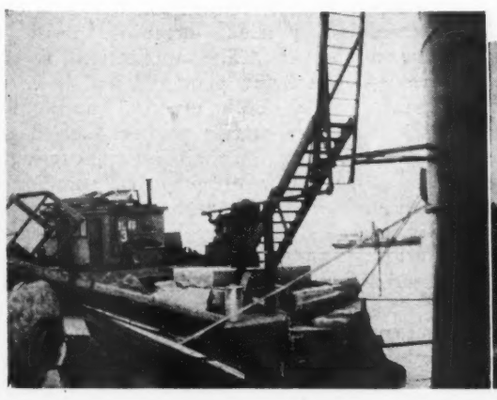
In the Ingersoll-Rand oil engine the solution of the problem is reached by positively controlling the point of ignition. A compression pressure of 125 pounds is employed. The resultant temperature is not high enough to ignite the fuel prematurely. The exact point of ignition is determined by a spark plug with timer and magneto. The fuel is injected by means of an ingenious type of metering pump. The nozzle is arranged so that the spray is directed tangentially to the piston in a horizontal plane. This arrangement, together with devices which whirl the incoming air, provides the turbulence which is so important in a solid-injection oil engine if complete combustion is to be obtained. The maximum gas pressures in the cylinder range from 300-350 pounds, which are comparable with those in a gasoline engine. As a result, it is possible to obtain the same dimensions and weight as would be expected in any conservatively designed and rated heavy-duty gasoline engine.

It was stated that the engine could be started by hand cranking. This is, of course, possible on account of the low compression. Normal starting is by means of an Ingersoll-Rand air motor and Bendix drive which occupy the same space and function in the same way as the ordinary electric starter. The starting motor operates on air at 100 pounds pressure supplied by the main compressor and stored in a special tank. Besides being simple, this method of starting has none of the disadvantages which result from admitting high-pressure air into the engine cylinders.

Returning to the work of installation: A block of concrete was poured on the rocks at the foot of the lighthouse. One of the new compressors was mounted on this block and connected to the foghorns. There it operated while the old units were being removed and the second new one was being permanently installed. Then the temporary unit was set up in the compressor room. By this procedure, made possible by the type and size of the units, the change was effected with a minimum of time and expense; and at no time during the substitution was the lighthouse without air for the fog signals.

VIEWS DURING THE CHANGE

The left and central pictures below show the compressor as temporarily set up at the foot of the lighthouse. At the right is a close view of the lighthouse while workmen were making the changes in equipment. The tank on the platform is an air receiver which provides a large supply of air and insures sustained operation of the foghorns



Now It's Canned Roses!

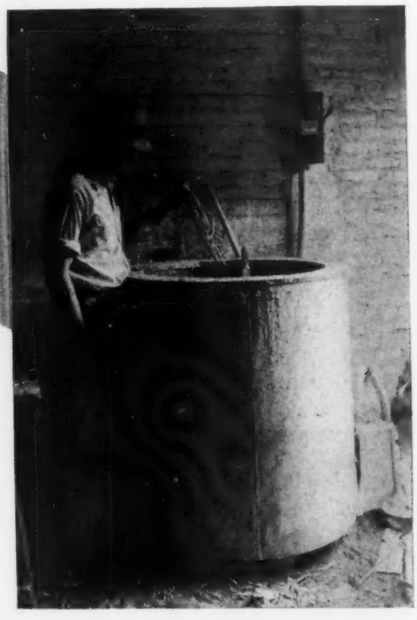
J. K. NOVINS

SELECTING STOCK

The roots of the cuttings are kept in damp sawdust until the bushes can be packaged. They are inspected regularly and only the healthy specimens are chosen for treatment.

TRIMMING TO SIZE

The plants are cut to uniform size for packaging—usually about 15 inches in length. This knife set in a ratchet frame performs the trimming operation.



APPLYING PARAFFIN

The upper portions of the cuttings are dipped in wax to preserve and protect them. Special electrical heating vats are provided to maintain the desired paraffin temperature.

BARGAIN Day at the Busy Corner Emporium, where thousands of shoppers mull around counters laden with packaged merchandise, packaged hosiery, canned pineapple —and canned roses! Yes, canned roses, put up in any variety to suit your aesthetic taste and ready for planting, or to send 3,000 miles or more to a friend in New York, San Francisco, or Oshkosh in the original air-tight containers. In fact, carloads of choice rose stocks cut in nurseries in California have already crossed the continent for display in department stores and other establishments, where housewives and businessmen buy them as they buy their table delicacies and their cigarettes—packaged!

Thousands of home gardens now bloom with many varieties of roses grown from the choicest stocks of packaged cuttings. One large California nursery today markets throughout the nation 1,000,000 rosebushes a year in packages designed for utility as well as sales appeal. A number of other nurseries that formerly confined themselves to local distribution have now entered upon large-scale production and distribution as a result of the development of special processes for preserving rose cuttings in airtight containers which withstand severe climatic conditions and the abuses of transportation and handling. Only recently a carload of packaged rosebushes made the journey from California to the Atlantic Coast unrefrigerated, and retained their freshness and vitality despite the months consumed in processing, warehousing, and transporting.

Rose cuttings, purchased over the store counter, can be planted package and all. Sun and soil will do the rest. Only the top portion of the wrapping need be removed to expose the bush to the sun. The roots, covered with a definite quantity of peat moss to keep them moist, survive the driest of soil conditions during the early stages of growth. It has been established by horticultural research that these packaged roses not only respond more readily to growth but are free from many of the common plant diseases that have troubled amateur and professional growers.

Until the special packaging process was developed, the industry was composed of comparatively small, scattered nurseries that served limited areas. Some of the larger concerns actually shipped quantities of rosebushes to distant markets, but at considerable expense. Aside from the fact that the cuttings had to be packed in bulky, unsightly boxes, only fast freight equipped with refrigeration could be used for long-distance shipments. And as the rosebushes had to be planted immediately upon arrival at the remote points, it was not feasible to merchandise the plants extensively in retail stores. Now some large nurseries have installed special machinery to prepare, process, and package the plants at extremely low cost, and a new industry has grown up over night.

Some 400 varieties of roses grown in California nurseries can now be bought over the counter in many cities and towns in the East and Middle West because some enterprising and observing nurseryman made the important discovery that cuttings could be preserved for unusually long periods by dipping them in hot paraffin. Possibly the thin layer of hot wax that mother poured over the fruit which she preserved in glass jars suggested the idea to him. It is well known that the film of wax renders the preserve airproof, free from contamination by minute organisms present in the atmosphere. The application of this process to a living plant did not, however, prove simple. Both practical nurserymen and experiment-station workers tackled the job of improving on the housewife's formula, and learned how to spray hot paraffin on delicate rose cuttings without destroying the living tissues. As a result of patient experimentation and the development of electrically heated paraffin vats, it is now possible to process rose cuttings in one nursery at the rate of 5,000 a day, and to package the product by mechanical means. It will be practicable in the near future similarly to preserve and

package many other flowers. Already the paraffin process has been used successfully on citrus fruits shipped from California packing houses to consumer markets in Europe and Asia. Applied by a patented process, the filmy paraffin covering protects the oranges and lemons from shrinkage during transcontinental and ocean transportation, and accounts for the healthy appearance of the fruit after storing and handling.

Applied at the correct temperature and in a thin enough coating, ordinary paraffin can preserve an entire season's growth of choice roses. Many experiments were conducted by nurserymen to determine the results of paraffin applications at various temperatures before they made any attempt to package their rose crops. If too hot, the melted wax burned the tissues, stopped their normal development after planting. If not hot enough, the thick coat of wax cooled and flaked off in big chunks, thus exposing the surface of the rosebush to contamination. Shrinkage of the stock invariably resulted when the paraffin melting temperature was permitted to fall below 160°F. These experiments laid the foundation for the more or less uniform practices now introduced in the larger nurseries, where the plants are successfully treated with hot paraffin at temperatures from 165° to 180°.

To maintain the paraffin at an even temperature, nurserymen have evolved the double-boiler-type electrically heated vat. The tank is 36 inches high, 30 inches in diameter, and has a 3-inch space between the galvanized iron walls. In the channel irons constructed on the outside of the inner wall are twenty 500-watt electric elements, producing a total of 10,000 watts. The remaining space in the 3-inch clearance is filled with magnesia powder, which acts as an insulator. An automatic thermostat regulates the temperature. As constant dipping tends to lower the temperature of the paraffin, the thermostat is vital to the correct processing of the rosebushes. The insulation helps to maintain a uniform temperature within the vat and to eliminate the chance of electric sparks coming in contact with the inflammable paraffin.

The preservative power of the melted paraffin is manifested by one grower who successfully treated cuttings of dahlias, tuberous begonias, cannas, and gloxinias, which were then held in storage from October to August—almost a year. Paraffin-coated gladioli bulbs were shipped across the Pacific and arrived in first-class condition.

One of the problems nurserymen had to solve before undertaking to package their rose stocks was how to protect them from mold. Extensive research demonstrated that paraffin, properly applied, would do this. It is believed that the hot wax kills the parasitic growths attached to the plant, and then forms a thin protective coat against further contamination. Special precaution is taken to remove all evidence of mold prior to dipping the cutting in the paraffin tank.

To obtain the right thickness of paraffin, the nurseryman times the dip to a fraction of a second. Withdrawing the cutting from the paraffin tank he shakes off the excess paraffin. The thin coating, having cooled very rapidly, is barely perceptible. In some nurseries special care is taken to keep the hot paraffin from coming in contact with the roots, which are separately wrapped in wet peat moss. The root cuttings are stored in damp sawdust until such time as it is practicable to package them. In storage the cuttings are regularly inspected, and only the healthy stock is marketed.

The next step is to prune the bush to a specified size, usually 15 inches, to fit a standard container. On a table where the pruning length is gauged, a knife in a ratchet frame prunes a bundle of bushes to the required length. The size selected is convenient not only for packing but also for planting.

After being pruned, the upper part of each plant is dipped in paraffin, and its roots are then encased in selected light-weight peat moss which has a high moisture content. The moss is compressed into a brick-like block by means of a hydraulic press, its finished size being such that it will fit snugly into the cardboard box in which it is to be marketed. That portion of the box which is to contain the roots is coated with tar so that it will retain the moisture. After the plant has been placed in the package, a flap is inserted on top of the moss to hold it in place. This has the effect of dividing the carton into two compartments and of holding the moss securely around the roots. As a final operation, the box is closed and hermetically sealed with glue, thus forming an airtight container in which the rose cutting will be preserved and protected during shipping and subsequent handling in stores.

Attractive boxes have done much to assist the merchandising of packaged rosebushes. Each bears on its side a pleasing and faithful reproduction in colors of the plant it contains. This not only promotes sales but also enables the shopper to select with ease the varieties wanted. For planting, it is necessary only to tear the upper portion of the container away and to insert the lower portion in the ground. The cardboard becomes soft from the moisture in the soil, and the growing roots are able easily to break through it and to spread out as they will. The sun melts the paraffin from the upper portion of the plant, which then undergoes normal development.

COVERING ROOTS

The roots are encased in damp, light-weight peat moss, which is molded around them in the form of a brick of a size that will fit snugly into the marketing container.

PACKAGING AND STORING

The treated plants are placed in cartons which have an interior coating of tar in that part which houses the roots. A cellophane window affords a means of inspection. Packaged plants are stored (right) until needed to fill shipment orders. Rose bushes marketed in this form are ready for planting by tearing away only the top portion of the carton.

Old Prints Show How Nation's

UNDERGROUND SHOWER

The workings were very wet and many of the workmen adopted Sou'wester attire.

SKETCH MADE BY JOSEPH BECKER ON NOVEMBER 27, 1873.

THE Hoosac Tunnel in northeastern Massachusetts has two claims to distinction: It was the first major tunnel-driving venture in the United States; and it marked the first practical use of compressed-air rock drills and of nitroglycerin in this country. On these pages we reproduce some sketches which were made by an artist for *Leslie's Weekly* in 1873, when the work was nearing completion.

At 3:13 o'clock on Thanksgiving Day, 1873, the tunnel was holed through. That was an occasion for much acclaim, for work on it had been in progress intermittently during eighteen years. Measuring only a few feet less than 4¾ miles in length, this railroad bore was quite the most prodigious thing of its kind attempted up to that time on this side of the Atlantic. Said *Leslie's Weekly*: "The Hoosac Tunnel is the greatest specimen of rock boring in the United States; and with the sole exception of the Mont St. Cénis cut, in the world."

Considering the handicaps that existed, the accomplishment was indeed something of a triumph. Throughout the prolonged period of work progress was impeded by difficulties of engineering, financial, and political natures. Hazardous conditions prevailed, and the toll of human life was heavy. Many lessons were well learned, however, and capitalized by subsequent tunnel builders.

The idea of a tunnel at the site eventually pierced was first advanced about 1825. Its purpose was to provide a passage through the mountains for a canal which was to link Boston and Troy and to create a water travel route from the Atlantic to the Great Lakes. The rise of rail transportation killed the canal scheme but heightened the agitation for the tunnel. Promoters of the projected Troy & Greenfield Railroad appealed to the Massachusetts legislature in 1851 for state financial aid in driving through the mica-slate core of the ridge near North Adams. Nothing came of the request, but it was repeated in 1853 and again in 1854. In March of the latter year the legislature promised to advance $2,000,000 as a loan, which was to have been repaid in installments. With this money in sight, the directors of the Troy & Greenfield let a contract in 1855 to E. W. Sewell & Company of Philadelphia. The price was $3,500,000. The railroad then sought to secure subscriptions from the communities along the line to be served; but public support was lacking and the contract was terminated without much construction work having been done. A new contract was let in 1856; but it was annulled because the state declined to subscribe to stock.

A third attempt to get the work underway was made in July, 1856, when Herman Haupt & Company signed a contract to drive the tunnel and lay the rails for $3,880,000. After a few months the stipulated sum was increased to $4,000,000. Five years later the state, having paid out $778,695, was dissatisfied with the way the operations were being
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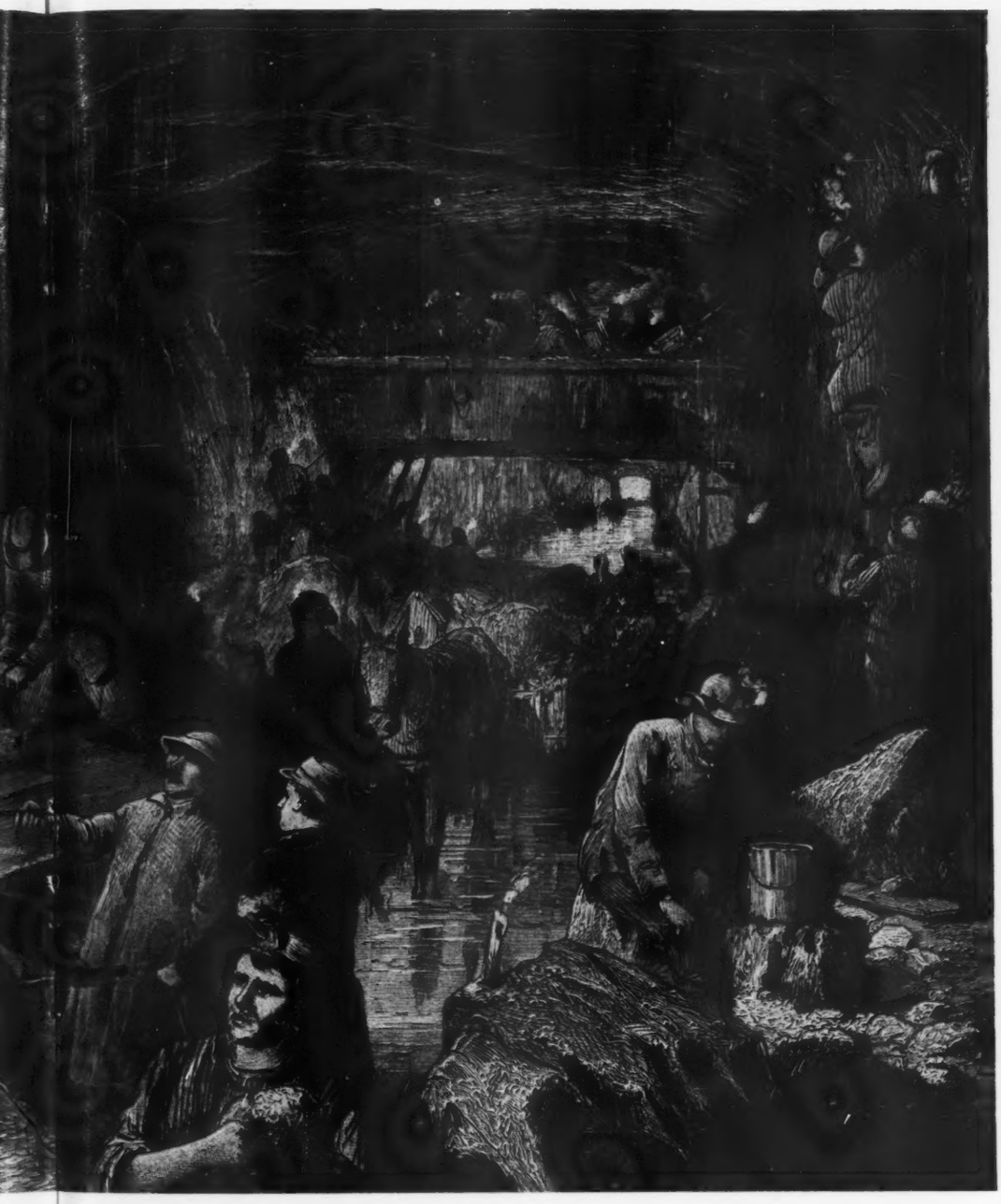
on's First Large Tunnel Was Driven



7, 1873. THE DAY PREVIOUS TO THE MEETING OF THE SECTIONS

THE LISTENING POST

As the two cuts drew near each other, sounds from the opposing heading could be heard.

being conducted, and on 1, the activities were sum- through the refusal of the er to approve the current ment.

e state undertook the task g the bore and prosecuted r four years. Meanwhile, money designed for excavat- d found its way into the officials of the common- increasingly frequent. These i a storm of charges of caused the state to relin- quish its direction of the work and to turn it over to Walter and Francis Shanley who agreed to complete the undertaking within five years for $4,594,268.

The tunnel was excavated to a section 26 feet wide and 26 feet high. The first step was the driving of a bottom heading, 26 feet wide and 8 feet high. Drillers working from staging then removed the remaining roof section. Working faces were opened from both portals and also from a central shaft. The sinking of this 27x15-foot elliptical section shaft to a depth of 1,028 feet was, in itself, a monumental undertaking in that day. The state carried it down 583 feet, and it was finished by the succeeding contractors.

Drilling was done by hand until 1866, when Charles Burleigh and two associates introduced some piston-type drills modeled after those which J. W. Fowle had made a dozen years before for use in the Mont St. Cénis bore through the Alps. About 40 of those machines were put in service; but they proved very expensive to operate because of excessive breakage, and were discarded. Burleigh then brought out an improved drill which was used until the tunnel was completed. One commentator placed the weight of this drill at 240 pounds, another at 540 pounds. In any event, as compared with modern drills, it was enormously heavy for its power. It struck 200 to 250 blows per minute—about one-tenth the operating speed of present drills—and was good for a maximum depth of hole of only 5 or 6 feet. Compressed air at 65 pounds pressure was supplied by specially built compressors.

Twelve drills were used at each working face. They were mounted six to a carriage, a mechanical device which originated on this job. According to contemporary accounts, the average service life of a drill before it required repairs was 50 hours; and for every drill in working condition there were three in the shop.

As our principal illustration shows, there was no power-driven equipment for handling excavated materials. The spoils were removed in cars drawn by mules over tracks laid on the bottom. Rocks too large for loading by hand were elevated by ponderous manually operated derricks. In the central section, water at times poured in faster than it could be pumped to the surface in the four lifts required. The workings were accordingly always partially submerged, and numerous deaths by drowning were recorded. Candles and miners' oil lamps furnished the only illumination.

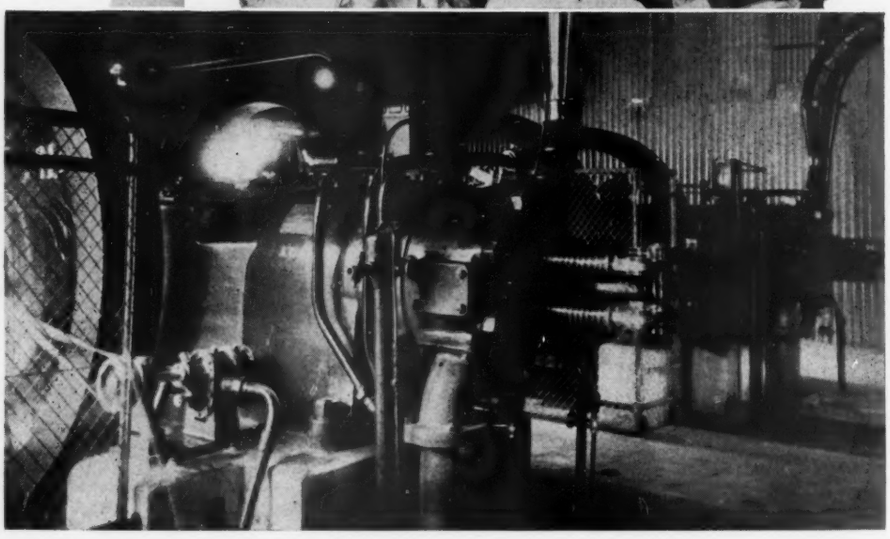
Blasting could not be done with black powder because the ventilation was inadequate to carry off the smoke that would have resulted. As a consequence, nitroglycerin, new at the time, was employed, although its cost is reported to have been ten times as great as black powder. The explosive was prepared on the ground by G. W. Mowbray, a leading chemist of that period.

EAST OF SUEZ

Human labor is relatively inexpensive, and does much of the work; but power-driven machinery also has its place. In the quarry here described most of the labor was Chinese. At the left is a group of coolies getting back to work following a blast. The figure in the pointed hat is a woman, one of six employed in the loading of rubble. Immediately below are shown some of the Chinese "powder monkeys" with two of the quarry staff. Captain Hamilton-Johnstone, author of our article and manager of the quarry, is in the center of the rear row. At the bottom are two of the oil-engine-driven air compressors that were in well-nigh continuous service.

A Granite Quarry in the Malay States

CAPT. E. D. HAMILTON-JOHNSTONE



TO the northeast of Johore Bahru lies Buckit Lounchu Quarry, which has supplied stone for the Singapore Naval Base which is being constructed by the British Government. It stands out as a red scar in a vast patch of intense green, for the countryside around Johore is almost entirely devoted to rubber estates.

The quarry was opened by the naval-base contractors, Sir John Jackson, Ltd., as a source of rubble and shaped stone. The rubble was crushed and delivered to the naval-base site for use as aggregate in the concrete employed in the many wharves and the dry dock which are being constructed there. Dressed stone, or ashlar, was also required in considerable quantities for copings and facings and for altars within the dry dock.

As the road goes, the quarry is 21 miles from the naval-base site; but by cutting a railway across a rubber estate on a direct line between the two points the distance the stone had to be conveyed was reduced to five miles.

In order to insure the large and steady output of stone essential to the successful conduct of building operations at the naval-base site, the contractors equipped the quarry with the best and most modern machinery available. Compressed air, which was vital to production, was supplied by four compressors, three of them stationary and the fourth portable. Two of the stationary machines were Ingersoll-Rand Type POC-2 units—2-stage, single-cylinder compressors each driven by a direct-connected oil engine. Each of these compressors delivered about 575 cfm. They proved economical and highly dependable. Except for brief periods, totaling perhaps half an hour when blasting was being done, they were in continuous operation day and night. This program was interrupted only once every six months, at which time the machines were shut down long enough to give them a thorough inspection. The third stationary compressor was an Ingersoll-Rand Class ES belt-driven machine which delivered approximately 350 cfm. The portable compressor, which was held in reserve for special jobs, had a capacity of about 250 cfm.

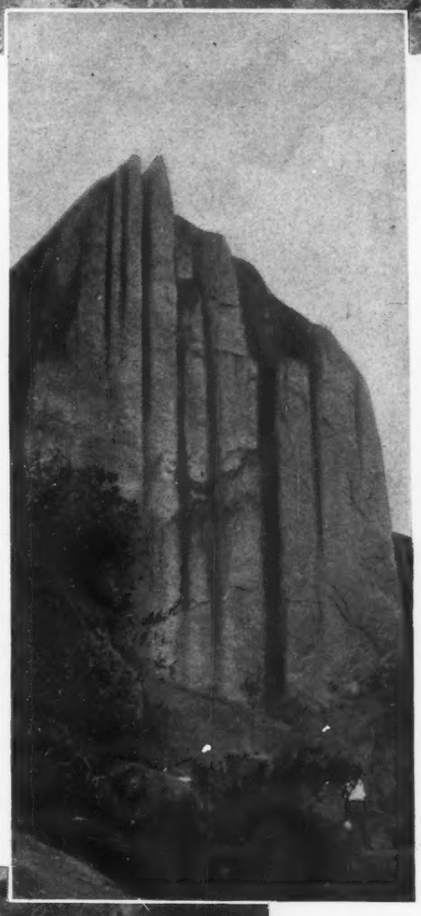
A 5-inch pipe line, which was assembled by means of Victaulic couplings, delivered the air to the quarry face. This type of pipe proved very successful because its flexibility permitted it to be laid readily over uneven ground. Leaks very seldom developed, and when one section of pipe became damaged from blasting it was a simple matter to remove it and replace it with a good section in a few minutes. For a considerable distance at the quarry end the pipe was reduced in size, as it was not expected that there would be any future development in that direction. Later on, however, when it became desirable to open up further workings in that zone, it was found that the air pressure was not sufficient

to operate the drills. This difficulty was overcome by the simple expedient of introducing an air receiver which would provide storage at the end of the line.

As opened up, the quarry provided a face approximately 650 feet long and 220 feet high. The intention was to work this by the well-known benching method, and this plan was followed as far as was possible. But the presence of a great number of fracture joints and fault planes running through the rock very often brought disappointment to those in charge of the quarry because of the failure of their efforts to maintain the face in workmanlike shape.

The scheme of primary drilling consisted of sinking a row of vertical holes 14 feet back from the face of the bench. These holes were spaced 16 feet apart and were carried to a depth of 20 feet. This drilling was done with six Ingersoll-Rand X-71 drifter drills mounted on tripods. The drill steel used was of 1¼-inch section. A "team", or crew, for each tripod drill consisted of one driller and three carriers of drill steel. These men worked in 8-hour shifts, the operations being carried on throughout the 24 hours of the day. An extra tripod was provided, and this was set up ahead of the working machines by an erector and two coolies. When a drilling crew finished its hole it moved on to this spare machine and continued work without any loss of time. The erector and two coolies then moved the tripod from the hole which had just been completed to the next drilling location along the line. The rock, a granite, was very destructive of drill steel, and the writer found that the most effective results could be obtained by changing steel after every 6 inches of penetration and by using a bit of 1/16-inch smaller gauge with each successive change. This required the use of 38 separate pieces of drill steel for each 20-foot hole.

The average rate of drilling was three holes per machine in 24 hours. This rate was slow as compared with that obtained during several tests which had been made in the quarry. On the occasion of these trials, holes averaging 19 feet 4 inches deep were drilled with air pressure ranging from 65 to 75 pounds in the over-all time of 1 hour, 15 minutes, and 45 seconds and in the net drilling time of 25 minutes and 5 seconds. This figured out to be at the rate of 3 inches per minute for over-all time and 9 inches per minute for actual drilling time. The slower pace at which drilling proceeded under actual working conditions may be attributed in part to the fact that all drill steel necessary was not at hand, as was the case during the test runs. Weather conditions also constituted an obstacle to sustained speedy work, as the rain gauge often showed a precipitation of as much as 3.75 inches of moisture in four hours. From time to time, also, one of the tripods had to be taken from the main face to be used in getting out blocks of ashlar, and, as it had to be moved a considerable distance, this tended to reduce the over-all drilling speed.



Secondary drilling was done with twelve "Jackhamers" which used 7/8-inch steel. These machines, ten of which were of the R-39 type, were operated in two shifts of twelve hours each at piecework rates. One carrier of drill steel served each drill.

It was necessary to recondition approximately 1,600 pieces of drill steel daily—700 of 1¼-inch size and 900 of 7/8-inch size. In addition to this requirement, the blacksmith shop had also to make up sufficient new drill steels to replace those worn out or lost in order to keep the total number up to the specified standard. To provide this service there were installed two I-R No. 50 drill-steel sharpeners and two I-R oil furnaces. Drill-steel bits were tempered in the usual

TWO PHASES OF THE OPERATIONS

In addition to supplying rubble for concrete, the workers were engaged in producing ashlar for walls, copings, and steps. This dimension stone was secured from large bowlders, some of them of mountainous size. The one pictured in the center was 95 feet high and 96 feet wide. At the left, native masons are at work reducing a bowlder to dimensioned pieces. Large blocks were broken by the plug-and-feather method. The finishing was all done by hand, more than 400 men being employed. In the rubble quarry primary drilling was done with modern, powerful drifter-type drills mounted on tripods. The top picture shows two of them at work.

QUARRY AND SHOP

Chinese became quite efficient blasters on this job. They loaded each hole according to directions on a card left there by the European supervisor who preceded them. Normally 40 holes were fired at a time, but as many as 90 were fired on some occasions. At the left is a section of the quarry face, photographed just prior to the blast of 55 holes which is shown at the bottom. In the center is the blacksmith shop and one of the native crews in charge of it. Approximately 1,600 pieces of drill steel were reconditioned there each day.

manner by Indian labor. Separate tanks for this purpose were provided for each type of drill steel. For the larger size the water was maintained 7/8-inch deep, and the supply was continually changed. The tank was equipped with brackets to hold the longer steels upright.

Primary blasting was done by a "team" consisting of one *kapala*, or headman, and six assistants who sprung, charged, and tamped all the holes. The European in charge of blasting placed beside each hole a card on which he had noted the amount of explosive to be used there. The natives followed these directions and became skillful and rapid in their work. An average of 40 holes was fired at a time, but as many as 90 were set off simultaneously. The firing was done by battery, except in a few cases where instantaneous fuse was used. An average of 18 pounds of explosive per ton was required. This figure could have been reduced materially by using powder of greater strength. However, at the start of operations the company had contracted for a large quantity of 58 per cent gelignite, and this was accordingly used. Tests indicated that, had it been possible to employ 75 per cent gelignite, the quantity required per ton of rock broken would have been reduced by about one-half, or to 10 pounds. These tests also showed that the higher-strength explosive would have broken more of the rubble to the required size, which was 3½ feet in largest dimension.

The same gelignite was used for secondary blasting, and the average amount required was about .05 pound per ton of rock. It is estimated that this figure could have been reduced to .02 pound if 75 per cent gelignite had been employed. This secondary blasting was done by four powder monkeys, who proved capable of charging and firing quite easily 200 holes per shift.

A series of tracks was maintained up to the quarry face, and the broken rubble was loaded into 6-cubic-yard dump cars, of which there were 92 in service. The loading was done by four cranes. One was of 10 tons capacity, another was a 5-ton special type, and the other two had been converted from draglines. The first two mentioned were the most satisfactory, as they were mounted on railway trucks and, in a short time, could be run out and away from the quarry face prior to blasting. These machines required very few repairs. The two converted draglines were mounted on crawler tractors and underwent a great amount of punishment in continually moving over the rough surfaces which they were called upon to negotiate. The rubble was barred by hand into skips which held about 2 tons. When a skip was filled it was hoisted by one of the cranes, and its contents transferred to a car. The average number of men engaged in the loading operations was 140, and the output ranged upwards of 40,000 tons of rubble per month. The loaded cars were drawn in the quarry by two 12-inch locomotives and on the main line by one locomotive of similar size.

In addition to the production of rubble, quarrying and preparation of ashlar or dimension stone constituted operations of considerable magnitude. About 400 native masons were employed in this work. The stone was dressed by hand, and satisfactory progress was made by this method. All labor in the quarry was Chinese, except the locomotive engineers, drill-steel sharpeners, and slashers.

Sir John Jackson, Ltd., maintain their home office in London. The resident director at the Singapore Naval Base is F. Du Sautoy.

Construction of the Hoover Dam*

How the Concrete Is Being Cooled as It Is Poured

LAWRENCE P. SOWLES†

THE plans and specifications prepared by the U. S. Bureau of Reclamation for the guidance of the contractors provide that the concrete in Hoover Dam shall be progressively cooled as it is poured and that a refrigerating plant shall be maintained for that purpose. It is usual to associate power shovels, rock drills, trucks, locomotives, and countless other mechanical agencies with the construction of a large dam, but the employment of refrigeration is, indeed, novel.

In view of the fact that some fairly large concrete dams have been built without the aid of artificial cooling and are today successfully holding back great volumes of water, the question naturally arises: Why was it considered necessary to include this unusual specification in this case, even though Hoover Dam is of unprecedented size? It will be the purpose of this article to answer this question, and also to describe the plant which the contractors have set up to do the prescribed work.

We are all familiar with the fact that bodies expand when they gain heat and contract when they lose heat. We have seen the bitumastic filling squeezed out of concrete pavement joints in the summer and have noticed those same joints open to a considerable distance in the winter. Similar changes take place in all structures which undergo temperature changes. Sometimes they are not of sufficient magnitude to be visible to the eye, but they are just as surely present. The pavement referred to is given room in which to move and thereby to relieve the tension or compression. If, however, there is no provision for movement, the effect of temperature changes is to set up internal stresses. The magnitude of these stresses varies according to the range of the temperature changes and the capacity of the body to adjust itself within so as to accommodate the internal strains. When the temperature stresses, plus the other stresses to which the body is subjected, exceed the resisting capacity of the structure, they manifest themselves in the form of cracks. These fractures are essential outbursts of strains, which must find relief either internally or externally. This cracking may or may not be of serious consequence, depending upon the service of the structure affected. In extreme cases it amounts to failure.

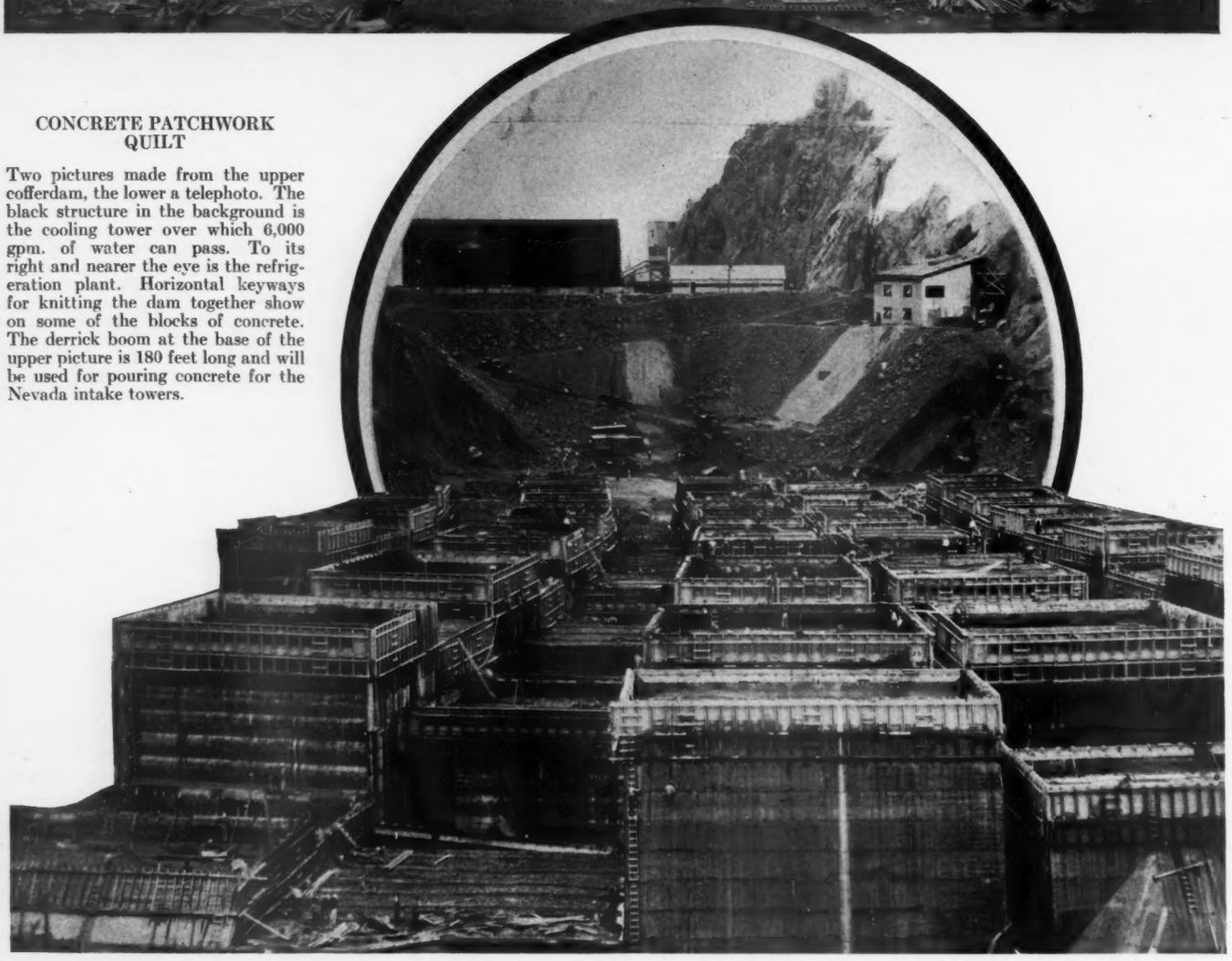
A dam of the gravity type, such as Hoover Dam will be, resists the pressure of the water behind it because its large mass is placed so as to give it the necessary stability. Such a huge volume of concrete undergoes seasonal and other temperature changes which set up enormous internal stresses. The greatest of these changes occurs during and shortly after construction, and arises from the setting action of the cement. Portland cement is a complex mixture of oxides, silicates, and carbonates of various elements. When water is added to it there is a chemical change, called hydration, during which are formed

THE ROOTS OF HOOVER DAM

General upstream view of the dam and Black Canyon as they appeared from the Government cableway on September 15, 1933. The division of the dam into a large number of columns for the pouring of the concrete by stages is clearly shown. The tops of the highest blocks are at elevation 640, which was about 6 feet below the mean low-water surface of the river before it was diverted. The top of the dam will be at elevation 1232, or 592 feet higher than shown here. At the center, in the foreground, is the inclined trestle on which the cooling-water mains enter the structure at elevation 560. This leads to the 8-foot slot, in the center of the dam, which can be easily traced. Close inspection of the right central area will disclose the fall lines from several of the overhead spanning cableways. At the left is the railroad, at elevation 720, over which some of the concrete is delivered from the Lomix plant just beyond the tunnel. A suspension bridge by which workmen cross the gorge shows at the top. The shovel on the upper cofferdam serves as a head tower for a "Joe McGee" bridle cableway which delivers materials on to the dam.

†Designer, Engineering Dept., Six Companies Inc.

**Sixteenth of a series of articles on the Colorado River and the building of the Hoover Dam.*



CONCRETE PATCHWORK QUILT

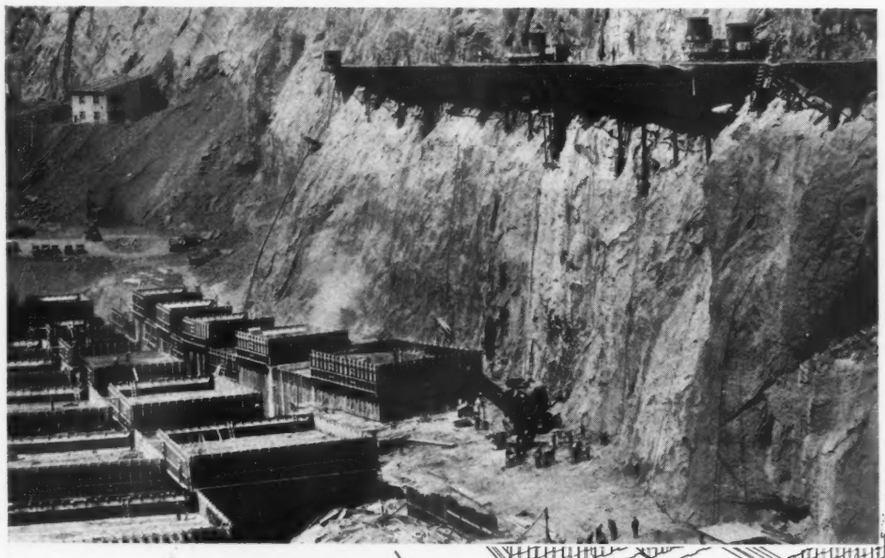
Two pictures made from the upper cofferdam, the lower a telephoto. The black structure in the background is the cooling tower over which 6,000 gpm. of water can pass. To its right and nearer the eye is the refrigeration plant. Horizontal keyways for knitting the dam together show on some of the blocks of concrete. The derrick boom at the base of the upper picture is 180 feet long and will be used for pouring concrete for the Nevada intake towers.

crystals which interlock among themselves and with the aggregates of the concrete to form a unified mass with high compressive and shearing strength. This process of hydration, which develops the strength of the concrete, serves to liberate a considerable quantity of heat. If this heat is not removed it raises the temperature of the concrete mass.

If the dimensions of the dam are reasonably small, this heat is soon dissipated by radiation and exerts no injurious effect upon the structure. Sometimes, to prevent the internal stresses from forming cracks upon the surfaces, sufficient reinforcing steel is added to give the structure the necessary resistive strength. Thus, while the temperature effects are present, they are absorbed internally. In large, unreinforced-concrete dams the heat of setting passes out by radiation from the surfaces exposed to the air and by conduction into the rock abutments, and since such unreinforced concrete is incapable of resisting tensile stresses, the shrinkage resulting from the cooling produces surface cracks. Except in the case of dams of the very smallest proportions, means are usually provided for filling these cracks at periodic intervals with grout, a neat mixture of Portland cement and water. Since the cooling progresses slowly, grouting may take place considerably after the structure is completed, the interval depending upon the shape and dimensions of the mass and the temperatures of the surrounding bodies to which it transfers its heat. If grouting is done before the cooling is complete, subsequent cooling of the mass towards its point of thermal equilibrium may produce further cracks which cannot then be grouted, and these fractures may endanger the safety of the dam. In any event, the cracks are usually unsightly and uneconomical.

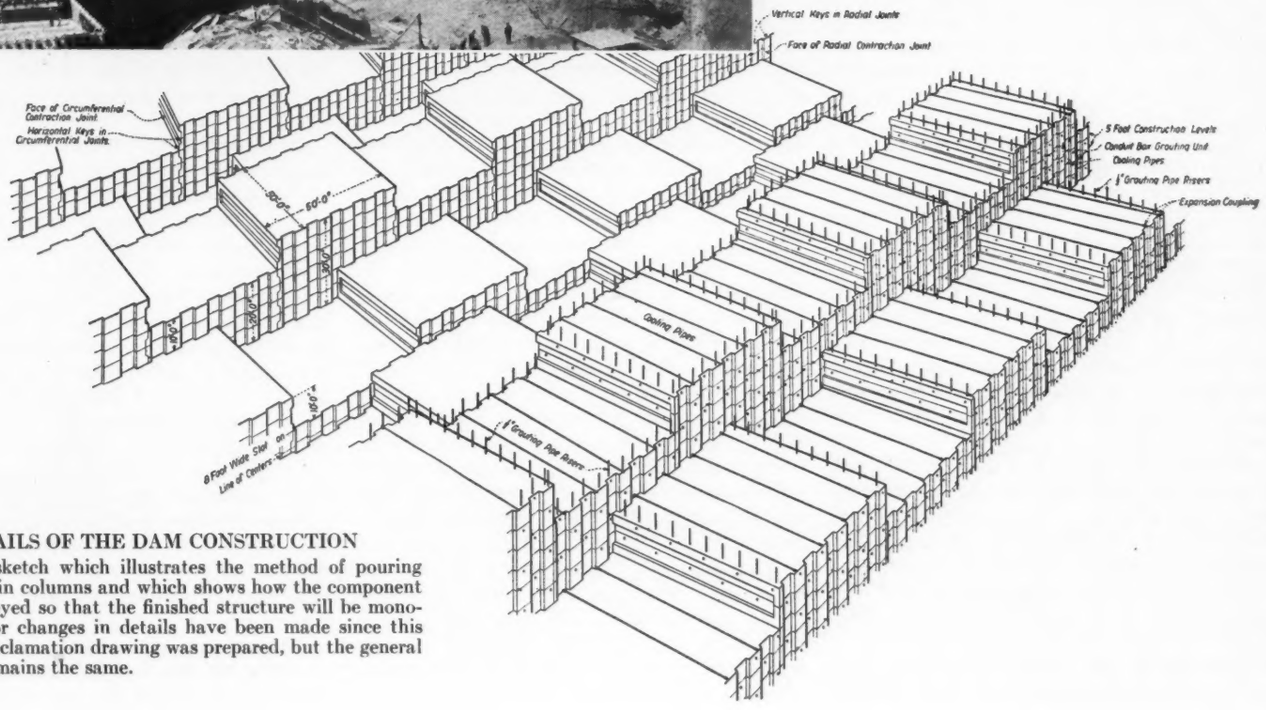
In a structure as massive as Hoover Dam, the heat must travel so far to reach the surface that an inordinate time would be required for cooling to progress to the point where grouting could be resorted to to fill cracks and thereby stop any existing or impending leakage. Indeed, in this instance, it has been computed that 125 years would have to elapse before grouting could be done with complete assurance that there would be no further cracking. To obviate this long wait and to exercise the greatest possible precaution towards making the structure immediately and permanently safe, it was decided: (1) to facilitate the dissipation of the setting heat by dividing the dam into a number of independent blocks and pouring these in definite stages in columns keyed together to form one compact mass when completed; and (2) to cool the entire structure by refrigeration to a point where there will be no subsequent temperature drop of sufficient magnitude to produce crack-forming strains. By following this procedure the cooling will be effected quickly, and upon its completion grouting can be done with every assurance that the individual blocks will be unified into a strong, secure, and enduring monolithic structure.

To determine the amount of cooling that would be required to reduce the temperature of the concrete to a safe point, the Bureau of Reclamation conducted extensive researches into the thermal properties of concrete. It was found that the average temperature rise resulting from the setting reaction would be approximately 40°F., and that the quantity of heat to be removed would be approximately 965 Btu's per cubic yard of concrete for each degree that it was to be cooled. This latter figure will vary slightly depending upon the



TRANSPORTING CONCRETE

Telephoto (left) of the Nevada footing and of the railroad at elevation 720 while two of the cableways are lifting buckets of concrete from cars. Note how the railroad is shored up. When built, the line rested on a fill at the edge of the river. The refrigeration plant is at the left, in line with the railroad.

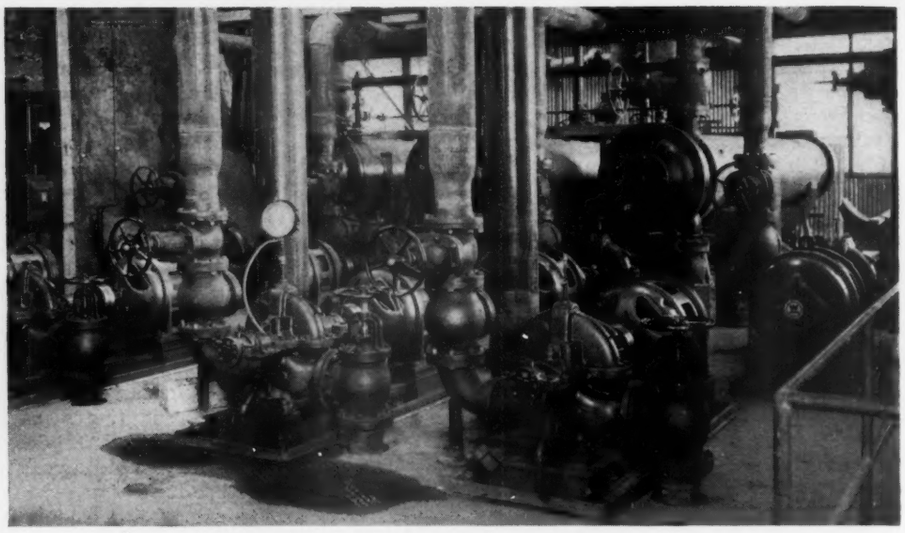


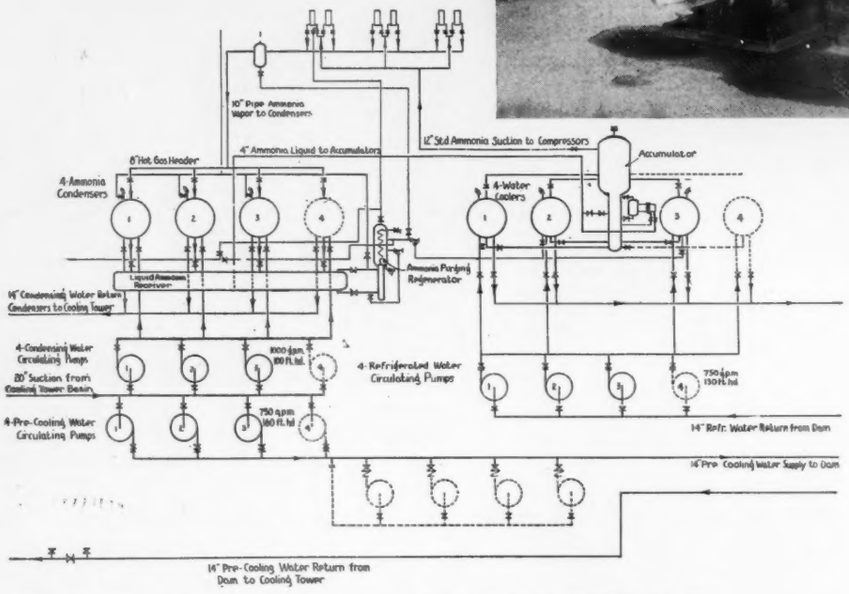
DETAILS OF THE DAM CONSTRUCTION

Perspective sketch which illustrates the method of pouring the concrete in columns and which shows how the component blocks are keyed so that the finished structure will be monolithic. Minor changes in details have been made since this Bureau of Reclamation drawing was prepared, but the general procedure remains the same.

PUMPS AND AMMONIA COMPRESSORS

Each of the three compressors (opposite page) has a capacity of 275 tons of refrigeration. They were used as air compressors during the early construction stages and then converted for their present service by substituting ammonia cylinders. Note the all-welded piping, which was photographed before it was insulated. The pumps in the foreground of the picture at the right handle precooling water. Beyond them are the refrigerated-water pumps. The horizontal cylinders in the background are the coolers in which heat is extracted from the refrigerated water returning from the dam.




10" Pipe Ammonia Vapor to Condensers
12" Std Ammonia Suction to Compressors
4" Ammonia Liquid to Accumulators
Accumulator
8" Hot Gas Header
4-Ammonia Condensers
4-Water Coolers
Liquid Ammonia Receiver
Ammonia Purging Regenerator
14" Condensing Water Return Condensers to Cooling Tower
4-Condensing Water Circulating Pumps
20" Suction from Cooling Tower Basin
4-Refrigerated Water Circulating Pumps
4-Pre-Cooling Water Circulating Pumps
14" Refr. Water Return from Dam
14" Pre-Cooling Water Supply to Dam
14" Pre-Cooling Water Return from Dam to Cooling Tower

FLOW SHEET OF THE CONCRETE COOLING PLANT.

composition and kind of cement used and upon the type and density of the aggregates entering into the concrete. To remove from the mass the 40° imparted to it by setting would therefore require the extraction of approximately 38,600 Btu's for each cubic yard of the 3,325,000 cubic yards in the dam.

At the time bids for construction were taken it was planned to cool the concrete by circulating through it refrigerated water by means of successive layers of 2- or 2½-inch pipes. These pipes were to be spaced on approximately 10-foot centers, arranged hexagonally in the concrete, and were to form series of loops extending from an 8-foot slot in the center of the dam out to the junction of the concrete and rock on either side. These coils were to be supplied with refrigerated water from headers in the central slot at their respective levels.

Following the issuance of the original specifications, the investigations as to the methods to be used in cooling the concrete were continued at the Owyhee Dam, which was then under construction. These later findings, together with certain changes in the form and arrangement of Hoover Dam, led to modifications of the plan previously outlined. It was decided to use 1-inch OD cooling tubes placed in horizontal layers on approximately 5-foot centers, spaced hexagonally. Under this plan approximately 3,500,000 feet—662 miles—of tubing will be embedded in the dam.

The tentative program provides that the concrete shall be cooled to a temperature of 45°F. at the upstream face of the dam and to approximately 65° at the downstream face, with a progressive range between these two points for the internal body of the structure.

The Bureau of Reclamation specified only the nature of the piping to be placed in the dam and left to the contractors' option, subject to the Bureau's approval, the design and arrangement of the cooling plant and piping required. The original specifications called for a cooling plant having a capacity of approximately 600 tons of refrigeration, sufficient to deliver 2,100 gpm. of water at the dam and to cool it through a range of from 47° to 40°F. As the plans developed, it became necessary to make provision for the additional requirement of 3,000 gpm. of precooled water to be taken from the river or from any other suitable source, as the contractors elected. This water is to be circulated through the cooling pipes before refrigerated water is introduced, and will suffice to cool the concrete through half the range from its initial temperature to the final temperature specified. Refrigerated water will then be turned into the same coils to complete the cooling process.

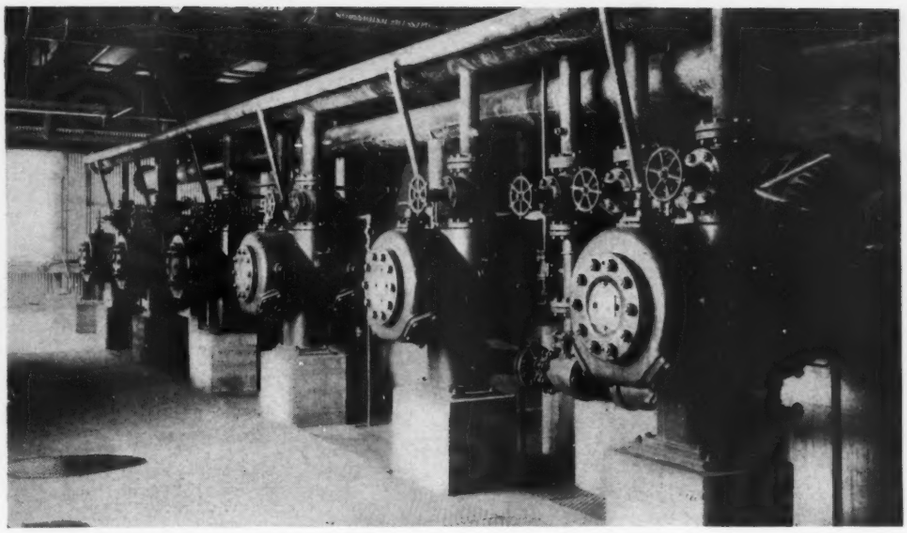
In view of these modifications, it devolved upon the contractors to provide a precooling-water system and a refrigerated-water system each of which could be operated independently and yet be made to combine their common parts so as to effect maximum economy in their construction. After studying cost estimates and analyses of a number of systems of the two classes, one of each was selected and final designs were prepared.

The precooling water, which is taken from the river, falls over a cooling tower, flows to the plant, is pumped through a supply line to the dam, circulates through the header and coil systems for cooling the concrete, and returns to the top of the cooling tower where the heat that it has taken up is extracted from it. It is then collected in a basin at the foot of the tower to begin another cycle.

The refrigerated water circulates in a closed system. It is cooled by the action of ammonia, is pumped through supply lines into headers supplying the loops in the concrete, and then returns to the plant for extraction of the heat taken up, after which it is recirculated.

Refrigeration is effected by an ammonia compression system similar in most details to those used in making ice. As is well known, ammonia boils or evaporates at a low temperature under a low pressure and at a correspondingly higher temperature as the pressure is increased. By regulating its pressure it is, therefore, possible to cause it to boil or evaporate at any desired temperature and to obtain any cooling effect wanted within the limits of its thermal characteristics. In making ice the pressure is varied so that the ammonia will boil at a temperature below the freezing point of water. In this case, however, it is not required that freezing temperatures be attained, and the compression system is, accordingly, arranged so that the ammonia will boil at a temperature of 37° F., which is sufficient to cool the circulating water to the desired point.

Ammonia under a pressure high enough to hold it in the liquid state is allowed to expand through a valve which lowers its pressure to



approximately 50 pounds to the square inch, which is sufficiently low to cause it to evaporate at a temperature of 37° F. In changing to the vaporous state it takes up enormous quantities of heat. Evaporation is caused to take place in a vessel through which the water returning from the dam at a temperature of about 47° is circulated at a rate just fast enough to permit the removal of enough of its contained heat to lower its temperature to 40°. After exerting its cooling effect the ammonia vapor is compressed and cooled sufficiently to liquefy it, ready to be expanded again.

The ammonia-compression equipment consists of four Ingersoll-Rand machines which were originally a part of the air-compression plant installed to supply air for operating rock drills and other pneumatic equipment during the early stages of the construction work. Six Companies Inc. selected these units with the idea of later transforming them into ammonia compressors, and this has now been done by substituting suitable compression cylinders for those previously used. Four units were thus converted, but one of them has so far not been put in operation. Each machine has two 10&10x14 single-stage cylinders. The compressors are of the direct-driven electric type, and were originally equipped with over-size synchronous motors of 250 hp. capacity to meet the added power demands following their conversion to ammonia machines. Each compressor has a normal rated capacity of 275 tons of refrigeration.

In these units the ammonia vapors resulting from the expansion are compressed to approximately 190 pounds pressure. Their discharge temperature is around 200° F., and in order to liquefy them it is necessary to cool them. This is done in a Braun shell-and-tube-type condenser equipped with Babcock & Wilcox tubes. There are three of these condensers, one for each compressor. Each contains 430 one-inch OD seamless steel tubes 20 feet long. Combined, they provide approximately 2,250 square feet of surface. Cold water circulates through the tubes in four passes, thereby cooling and liquefying the ammonia vapors which are circulated around the tubes. Each of these condensers weighs about 8 tons. Their shells are of welded steel plate with welded integral tube sheets in which the tubes are expanded.

The liquid ammonia passes from the condensers to a welded steel receiver 30 inches in diameter and 17 feet long. Beside the receiver is a Gay purging regenerator for removing in one operation noncondensible gases from the system and also oil originating in the compressors. This is accomplished with the aid of ammonia from a high-pressure oil trap, which will be mentioned a little later. The evaporation of this ammonia condenses out and recovers the ammonia which is mixed with the noncondensible gases drawn from the various purging connections with the condensers, coolers, and accumulator. The piping is so arranged that the regenerator may be used for pumping out and evacuating any particular section or unit of the equipment upon which it is desired to work.

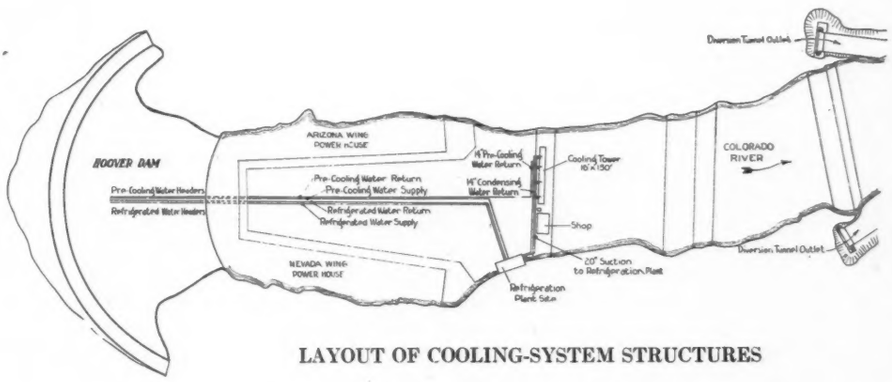
The condensing water is obtained from the same cooling tower used for the precooling-water system. This tower has a capacity to cool 6,000 gallons of water per minute through 75° F. to within 5° of the wet-bulb temperature specified at 75° with a wind of five miles per hour. It is built of redwood, and is 143 feet long, 16 feet wide, and 43 feet high. The water is distributed at its top by a 10-inch, redwood, stave header which has spray nozzles at 1-foot intervals. The tower was supplied by the Foster-Wheeler Company through the Consolidated Steel Company of Los Angeles, and was erected by Six Companies Inc. The lower cofferdam, on which the tower is located, will be removed after Hoover Dam has reached a height sufficient to permit storage to begin behind it. This will necessitate dismantling the tower; and it is expected that precooling and condensing water will thereafter be drawn from the reservoir.

Just before the ammonia vapors enter the header which supplies the condensers they pass through a high-pressure trap which captures particles of oil that may have passed over from the compressors and that would coat the heat-exchange surfaces and reduce their efficiency if not removed. This is a cylinder, about 18 inches in diameter and 4 feet high, which has a drain connection at the bottom and a purge connection at the top, where there is also a baffle set transversely to the flow of the ammonia vapor.

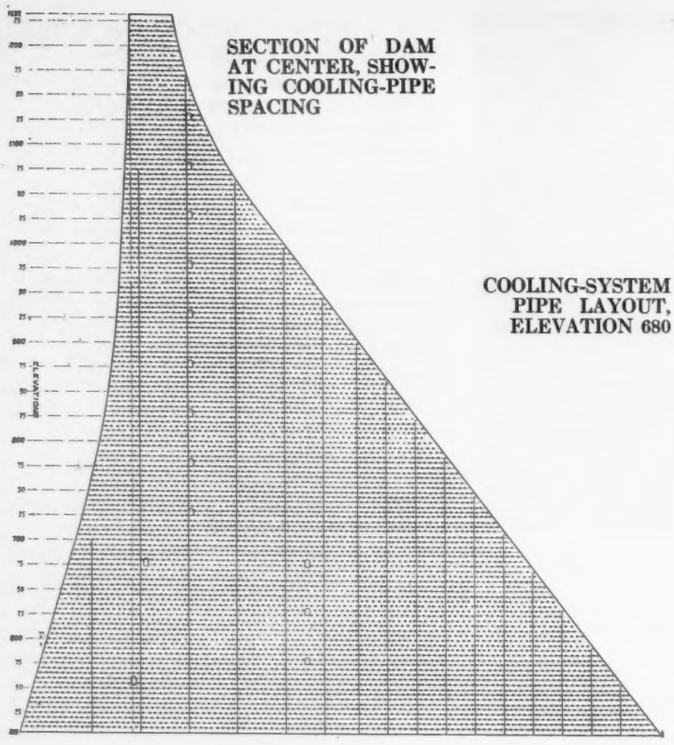
The exchange of heat between the return water from the dam and the ammonia takes place in three water coolers. These, like the condensers, are of the shell-and-tube type. The shell is a welded steel cylinder 30 inches in diameter and 20 feet long. Each cooler contains 375 one-inch OD stainless-steel tubes through which the water passes while the ammonia evaporates around them. The tube sheets are integral with the shell and are of heavy 2-inch construction to enable them to resist the pressure of the 600-foot head of water that will be met when the concrete in the top portion of the dam is being cooled.

The liquid ammonia is supplied to the coolers by a reservoir known as the accumulator. Six-inch ammonia-vapor return lines extend from the coolers to the accumulator to permit entrained particles of liquid ammonia to return to the vessel. The gaseous ammonia then goes to the compressors through a suction line which is taken off one side and near the top of the accumulator. To allow ample vapor-disengaging space, the accumulator is larger at the top than at the bottom and its upper 7-foot section is 4 feet in diameter while its lower 7-foot section is only 18 inches in diameter. On one side and in its lower part is a connection for a York 2-inch float control valve which automatically regulates the liquid level in the accumulator and coolers. There is a 4-inch liquid-ammonia inlet from a hand-operated expansion valve and a 2-inch inlet from the float control valve.

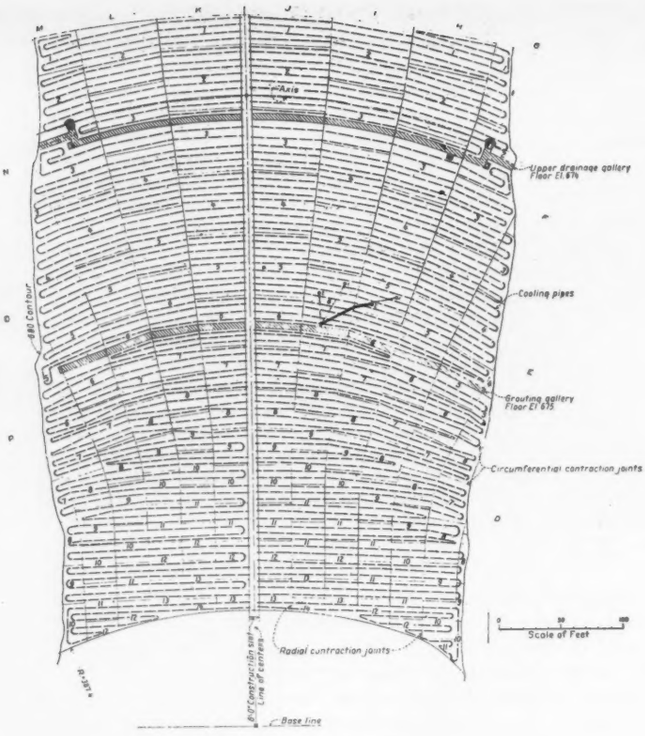
All-welded piping is used for the plant am-



LAYOUT OF COOLING-SYSTEM STRUCTURES



SECTION OF DAM AT CENTER, SHOWING COOLING-PIPE SPACING



COOLING-SYSTEM PIPE LAYOUT, ELEVATION 680

monia system, flanged as required to accommodate fittings and connections to vessels. All lines, valves, fittings, and apparatus containing water or ammonia at low temperatures are insulated with 2 inches of cork surrounded by finished plastering and then painted to give a neat appearance.

It is anticipated that approximately 23 months will be required to complete the pouring of the concrete, during all of which period cooling water will be circulated through one or more of the various levels as the huge structure grows higher. Failures in the circulatory system would cause costly delays in the contractors' schedule, and it is, accordingly, of vital importance that the pumping equipment be both efficient and reliable. There are three sets of pumps, each of which performs an individual service. The first set —the precooling-water pumps—consists of four Cameron No. 4 ANV units, each of which has a capacity of 750 gpm. against 160 feet of head. They operate at 1,750 rpm., and are each driven by a Westinghouse 50-hp. motor. These pumps are intended to supply precooling water until the dam reaches elevation 750, which will be about one-third of its ultimate height. For service above that level will be installed booster pumps to operate in conjunction with the present pumps. They will serve to circulate the precooling water up to elevation 950. These booster units will each have a capacity of 750 gpm. against 200 feet of head, and will be designed for case and gland working pressures of 300 pounds. At the time they are being installed, the impellers of the present pumps will be changed to increase their head capacities to 200 feet.

Another set of pumps circulates the refrigerated water through the refrigerating plant and dam cycle. There are four of these, of which three are operated and one serves as a spare. These are Cameron No. 4 BNV units, built with extra-heavy casings to withstand 400 pounds pressure at the shut-off. Each pump has a rated capacity of 750 gpm. against 130 feet of head, and is operated at 1,750 rpm. by a Westinghouse 40-hp. motor.

The third group of pumps handles the water used to condense the ammonia vapors. These are four Cameron No. 5 LV units, each with a rated capacity of 1,000 gpm. against 100 feet of head and driven at 1,750 rpm. by a Westinghouse 40-hp. motor. Three are used at a time, the fourth being held in reserve.

A considerable length of large-diameter pipe is required to connect the refrigerating plant, the dam, and the cooling tower. A 20-inch line, 220 feet long, carries precooling and condensing water from the tower to the plant. Precooling water goes to the dam through a 14-inch line and is returned through another of the same size to the base of the cooling tower where it passes through two 10-inch risers to the distributing header at the top. Two 14-inch lines between the plant and the dam provide for the supply and return of the refrigerated water. The refrigerated-water lines are insulated with 2 inches of cork to reduce temperature rises in summer and to guard against freezing in winter. All these major lines are buried and backfilled with fine sand from the river bottom.

The U-shaped power plant will occupy the space just below the dam, with wings extending along each canyon wall. To minimize the difficulties of carrying the four 14-inch water lines up the face of the dam through the powerhouse construction it was decided to place them in the slot where they would be out of the way. When the cooling of the lower portion of the dam is completed, and the slot is concreted, these lines will remain embedded. Connections from them will be run out to the edge of the downstream face above the roof line of the power house, and from that point upward they will be carried along the face. The arrangement of this piping is illustrated.

To distribute the water from the 14-inch supply mains to the 1-inch cooling coils, a 6-inch header is run through the slot at either side, there being two supply headers for precooling water and two for refrigerated water. Connections to the inlet ends of the various cooling coils are taken off the headers by means of piping and 1-inch hose connections. Similar connections from the outlet ends of the coils to another pair of 6-inch headers are made for the return water. The 6-inch supply headers are taken off a common 8-inch cross header from each 14-inch supply line, and these are so manifolded that it is possible to supply either precooling water or refrigerated water by operating control valves. Similar 8-inch cross headers receive the return flow of the 6-inch headers and direct it to the respective return systems by means of valves.

As concreting progresses upward, sets of 6-inch headers are installed at various levels, as required by the number of cooling coils to be operated. In that portion of the dam midway between the bottom and the top, between approximate elevations 600 and 900, a set of these headers will be needed every 10 feet. An initial installation of approximately ten sets of headers will be required to supply water to all the coils which will be operated simultaneously. The lower four sets will be carrying refrigerated water and the upper six precooled water. As cooling by means of each level of coils is completed, the headers will be dismantled and reinstalled above the top set of headers then operating so as to provide cooling for the newest level of coils. As soon as each installation is made, precooling water will be started circulating. After pre-

cooling has been completed as specified, the valves at the manifolds from the 14-inch supply and return lines will be changed so as to shut off the precooled water and turn on the refrigerated water. This cycle will be repeated throughout the height of the dam, and each set of headers will be reinstalled approximately six times as the cooling is carried on at progressively higher levels.

The fabrication of the approximately 20,000 lineal feet of 6-inch headers that will be required is being carried on at a pipe shop on the lower cofferdam. All the connections for the supply and return lines for the cooling coils are welded on there. The headers are covered with 2 inches of cork insulation, and the pipe is trucked in 20-foot lengths to the dam and there set in place by cableway or by such other method as seems expedient for that level. These headers are supported in the slot by steel brackets made fast to the bolt anchors which have previously been used to hold the concrete forms in position. A walkway is provided at each level for placing these pipes, and a roof is maintained above the top level operating or being installed to protect the workmen from falling objects.

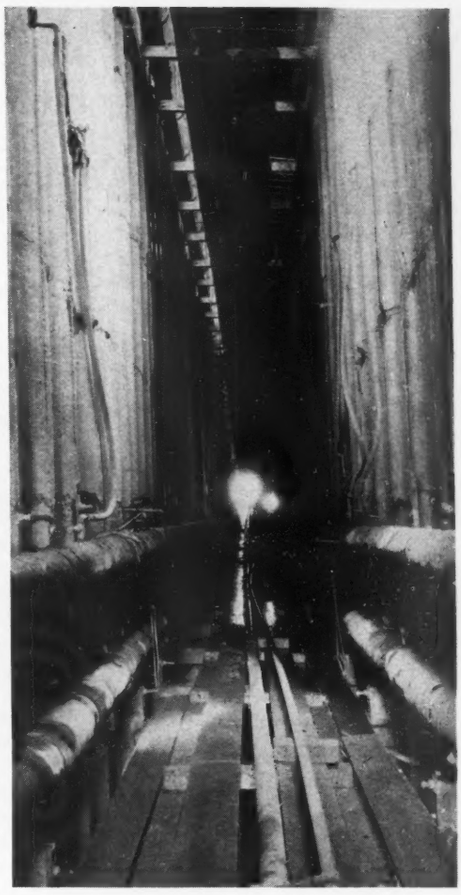
A tentative procedure of cooling operations, as specified by the Bureau of Reclamation, has been set up and used, but it is subject to such variations as prove expedient during the progress of the cooling. At present the control procedure embraces the following steps: obtaining starting temperatures of the concrete; adjusting the flow of water through the pipes; checking the progress of cooling; and checking the completion of cooling.

The Bureau of Reclamation has provided several methods for measuring the temperatures of the concrete and of the water entering and leaving the coils. There are being placed in the concrete, at the time of pouring and at a number of points in different levels, a series of thermocouples and resistance thermometers for determining directly the temperature of the concrete. The Bureau also has prepared a series of charts to enable its inspectors to determine, by a very simple calculation, the progress of cooling by measuring the water entering and leaving the cooling loops. Several variables are involved in determining the time required for cooling, namely: number of days cooling has proceeded; initial temperature of the concrete; present temperature of the concrete; the temperature difference between the water entering and leaving the coils; the number of days required to complete cooling; and the final desired temperature of the concrete. When certain of these variables are known, either specified or from field data, it is possible by using the charts provided by the Bureau to determine the values of the unknown variables in controlling the cooling. Starting concrete temperatures are taken before cooling begins by means of resistance thermometers embedded in the concrete at points between the embedded cooling pipes and also by means of resistance thermometers inserted various distances into the cooling pipes. This determination is being made for all coil zones prior to starting cooling.

The Bureau of Reclamation has determined that 4 gpm. is the most desirable rate of flow through the cooling coils. Inasmuch as the loops are of various lengths, the flow through each of the various coils from a set of headers must be regulated to compensate for these differences. A connection has been provided for the insertion of a meter in each loop for the direct measurement of the flow. As soon as a level of coils has been placed in operation, the loops are all regulated so that water at the rate of 4 gpm. flows through each.

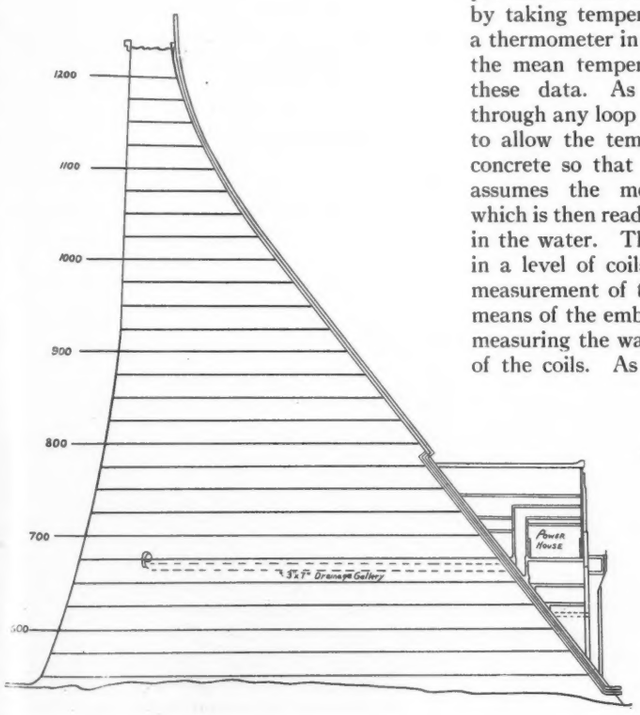
As cooling progresses, measurements are taken to check the progress of the cooling. This may be done by drawing water samples into thermos flasks through small pet cocks provided at the inlet and outlet of each coil—by taking temperatures directly by inserting a thermometer in each sample and calculating the mean temperature of the concrete from these data. As an alternative, the flow through any loop may be stopped for 48 hours to allow the temperature to equalize in the concrete so that the water lying in the coil assumes the mean concrete temperature, which is then read by a thermometer immersed in the water. The completion of the cooling in a level of coils is checked both by direct measurement of the concrete temperature by means of the embedded thermometers and by measuring the water temperatures in and out of the coils. As soon as the cooling in any particular loop has been brought to the desired final temperature, circulation through the loop is stopped. The quantity of water supplied by the plant to the dam for both precooling and refrigeration is determined by the number of loops operating upon each circuit, since each coil requires a flow of 4 gpm.

Grouting of the radial and circumferential contraction joints is begun as soon as cooling has been completed in a 50-foot grouting lift, and all the headers and staging are removed from the slot within the elevations cooled. The 8-foot slot is filled with concrete while grouting is proceeding. This operation of grouting and cooling makes the mass of the dam in each grouting lift a unified body of concrete with all temperature strains positively cared for. When this consolidating grouting, following the cooling, has been completed, the designer has a positive assurance that the mass of the dam will act exactly as intended in resisting the load imposed upon the structure by the pressure of the water impounded behind it.



WHERE THE HEAT ESCAPES

Walkway at one level of the 8-foot slot through the center of the dam. The two pipes at either side are 6-inch insulated headers for supplying and returning the water which absorbs the heat generated by the setting of the cement. This is the first set of headers installed and it serves all cooling-pipe coils between elevations 525 and 575. Hose connections to some of these loops can be seen. The slot is roofed to prevent injury to workmen from falling objects.



SUPPLY AND RETURN LINES

During the pouring of the lower portion of the dam, the 14-inch precooling- and refrigerated-water mains will be carried upward in a slot so as not to interfere with the building of the central portion of the power house. Above the roof of that structure they will be run up the downstream face of the dam.

Saving Money on an Emergency Drilling Job

CURBING A ROCK SLIDE

Rock loosened by heavy rains threatened to slide down the steep slopes of a Santa Fe Railroad cut in New Mexico and to tie up the line during a period of heavy fruit shipments from the West Coast. The danger was averted by drilling and blasting away the unstable material. Above is shown a portion of the cut, with the tie-tamper air compressor from which a 2-inch line was run to the top of the cliff to supply the drills. At the left are pictured "Jackhamer" men suspended by ropes while drilling in a location of insecure footing.

EASTBOUND Santa Fe fast freight and express trains detour near Albuquerque from the line of the old Santa Fe Trail to a more nearly level route through the Texas Panhandle. This is one of our fastest and most popular transcontinental freight lines and carries quantities of such diverse products as citrus fruits from California, beef cattle from ranges of the Southwest, and raw silk from the Orient.

Santa Fe type locomotives, weighing as much as 250 tons and working in pairs as puller and pusher, follow exacting schedules in hurrying through the upper Rio Grande Valley and over the Manzano Range long trains of California perishables destined for eastern consumption. Increasingly attractive because of unique scenic and climatic values, this section wears a mantle of history quite as old as that of Boston or Jamestown. These Manzano (apple) Mountains boast a Spanish orchard 400 years old; and their ruined Gran Quivera, once a huge apartment house, baffles archaeologists with its adjoining well-engineered irrigating system whose source of supply disappeared centuries ago. Much of the aura of the Indian and of the Spaniard remains; and the locomotive, whose ten drivers deliver 93,000 pounds of tractive force, passes carts and wagons drawn by ponies and burros of fractional horsepower.

In a deep cut near Sais, N. M., during August of this year, successive heavy rains permeated strata of schists and shales in a quartzite formation and caused a slide whose instability had been under surveillance by division forces for several weeks. Two American ditchers, which had been held in readiness, provided means for clearing the track with only a few hours' delay to train service in the event of further earth movements. But slight shifting of a considerable volume of rock made it necessary to take down about 15,000 yards to put the cut in safe condition. Cantaloupe movement from the Pacific Coast and from the Rio Grande Valley was in full swing, making it imperative that rock be shot down in relatively small quantities so as to avoid the possibility of interference with train schedules. A 7x6 tie-tamper air compressor, which had seen widely diversified service in four states since its purchase in 1927, was utilized to operate an S-49 and an R-39 "Jackhamer" in doing requisite drilling.

Prior to the time mentioned, the unit cost of hand-sharpening drill-steel bits on jobs of this character always had been excessively high because of the necessity of keeping a blacksmith and a helper on hand for considerable periods during which comparatively little drilling was done. In this particular instance this expense for labor was eliminated by using detachable "Jackbits".

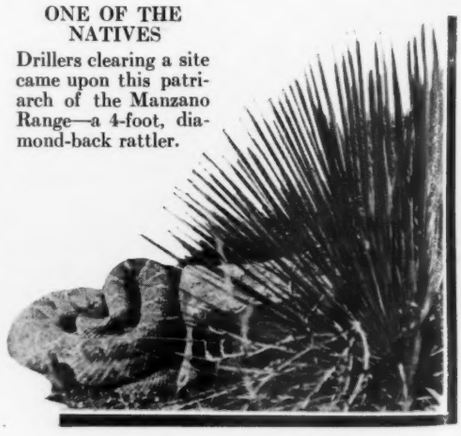
Drill runners worked in pairs and in locations where the foothold was precarious—they were suspended on ropes from above. Since the weight and the bulk of the necessary "Jackbits" and rods were only about one-fifth as much as they would have been for the requisite sets of conventional drill steel, the problem of supplying the drillers was simplified and the item of transportation of drilling equipment to the site in baggage cars was likewise made easier.

The use of the precisely formed bits of dependable gauge contributed to the economy of drilling. An average of 10 feet of hole per bit was obtained without regrinding in rock containing seams of very abrasive volcanic material. This compared favorably with the practice of sharpening steels after every 2-foot round in a nearby quarry.

Spoils were loaded with locomotive ditchers and dumped on nearby fills. An interesting feature of the job was the employment, with the exception of the powderman and ditcher operators, of local section forces in handling all the work. The operation was in charge of Roadmaster J. E. Logsdon.

ONE OF THE NATIVES

Drillers clearing a site came upon this patriarch of the Manzano Range—a 4-foot, diamond-back rattler.



UNDERGROUND TRANSMISSION LINE FOR SWISS POWER PLANT

LOFTY transmission towers carrying electric lines are familiar to most of us and are the accepted means of delivering current from remote generating stations to industrial centers. Under normal conditions they are highly satisfactory; but in mountainous regions, where snow slides have to be reckoned with, they will not do. It was because of the ever-present menace of avalanches that a part of the transmission line of the great Oberhasli hydro-electric development in the Bernese Alps of Switzerland has been carried underground.

The power plant, situated at Handeck, obtains its water supply from two artificial lakes that lie more than 6,000 feet above sea level. These bodies of water have a combined capacity of approximately 4,000,000,000 cubic feet, and impound the run-off of a watershed, largely of a glacial nature, covering an area of 43 square miles. Grimsel Lake, with a maximum length of 3.5 miles, is the larger, and is formed by two dams—the Seeuferegg and the Spitallamm. The latter is the biggest of its kind in Europe. The building of these structures at such an altitude and under conditions that permitted a working period of but three months each year represented considerable difficulties, as described in a previous issue of COMPRESSED AIR MAGAZINE.

From Lake Grimsel the water is fed through a horizontal tunnel to Lake Gelmer about three miles away. Thence it flows under a head of 1,750 feet to the generating units in the power house—the 8-foot steel penstocks being carried through a tunnel 3,700 feet long and reaching a maximum inclination of 72 per cent. Each of the four vertical-type generating units consists of a 30,000-hp. Pelton wheel and a 28,000-kva. generator producing current at 11,000 volts. This is stepped up to 50,000 volts and transmitted by four underground cables to Guttannen, from which point as many overhead wires deliver it first to Innertkirchen and then, after having been stepped up there to 150,000 volts, to central Switzerland. The tunnel for the underground cables has a length of 3.1 miles and is large enough to accommodate a small electric passenger car which is the only means of communication between the Handeck station and the Village of Guttannen in the wintertime.

It is now proposed to increase the capacity of the system by making some of the water do double duty. The plan is to erect another power plant near the present Innertkirchen transformer station; to impound the water from the Handeck turbine outlets; and to convey it through a tunnel and penstocks to that power house.

LUBRICATING YARN OF PURE WOOL

COTTON waste, which is so extensively used in the lubricating of axle boxes and armatures, may have to go into the discard if the claims made for a substitute material recently placed on the market be true. The new packing is sold under the name of Airedale lubricating yarn. It is supplied in 10-pound packages and is ready for immediate application—requires no soaking or draining.

The product is of British manufacture, and has been developed after years of study of textile fibers of all sorts and from different localities, of yarns and yarn mixtures, of thread thicknesses, and even of the amount of twist so as to give the yarn a maximum of life. Pure wool was determined upon as the raw material best suited for the purpose because a pound of it will hold about a gallon of oil, or twice as much as cotton waste. With this fact established, available impregnating oils were scrutinized. The outcome of the latter investigations is a new lubricant—a high-grade mineral oil carrying a certain percentage of wool-wax alcohol. The compound is said to have exceptional penetrative qualities and a great affinity for mineral oil with virtually no free fatty acid content. The result of all this research is a yarn that is described as possessing a high degree of durability, elasticity, capillarity, and lubricating properties.

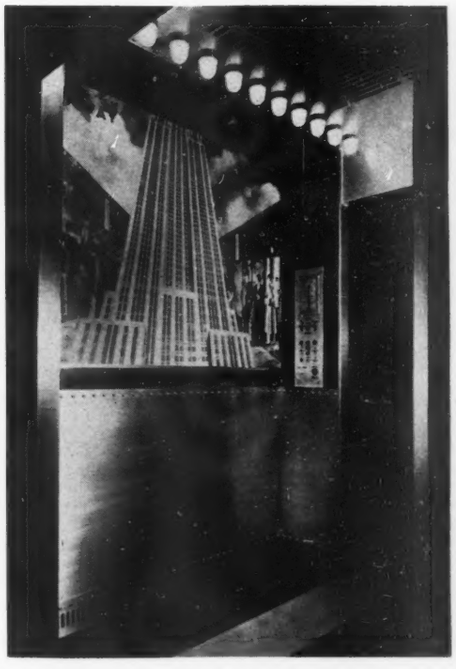
Based on 80,000 car-miles a year under normal operating conditions, Airedale lubricating yarn has an estimated life of six years in the axle box as compared with one year for cotton-waste packing. At this writing the material is being tried out on a well-known African railroad, with the following results: Upon inspection of the test locomotives after the usual running period, the packing and bearings were found to be in such good condition that they were not touched. After a second run of like duration examination revealed that the bearings were not worn and that the packing was still in good shape, so that the engines were sent out a third time with the original lubricating yarn in the axle boxes. With cotton waste it would have been necessary to replace the bearings and to repack the boxes at the end of each run. Airedale lubricating yarn is now the standard packing on this line.

Elevator Murals to Calm Riders' Nerves

A NEW note in interior decoration has been struck by the Otis Elevator Company in the case of the cars built for the towers of the Skyway Transporter Bridge at the Chicago Century of Progress Exposition. Striking photographic murals, emphasized by bright lacquer bands, are set in highly polished metal walls whose only other adornment are the heads of the rivets that bind the structural parts.

The murals depict the past and present methods of reaching the upper floors of buildings; and, aside from their decorative value, so the Otis Elevator Company explains, are intended to have a psychological effect on the occupants, to destroy that unpleasant shut-in feeling that some people experience when riding in the modern all-enclosed type of car.

Another interesting feature of these new elevators are the floors of shatterproof glass. These enable the passengers to look straight down the shafts and to follow the movements of the hoisting machinery, of the automatic-control equipment, and of the safety devices of a thoroughly up-to-date system of vertical transportation.



Save Valuable

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It pays to find a Goodrich Distributor when